# HUMAN VITALITY AND EFFICIENCY UNDER PROLONGED RESTRICTED DIET

BY

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# HUMAN VITALITY AND EFFICIENCY UNDER PROLONGED RESTRICTED DIET

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# INTRODUCTION.

For many years the Nutrition Laboratory has been studying the possibility of variations in nutritional levels, searching more especially for individuals or classes of individuals with a noticeably low metabolism. To this end evidence has been sought in experiments with a man having but one lung; with individuals claiming to subsist upon considerably less food than an ordinary individual; with vegetarians; with a man fasting for a period of 31 days; and with diabetic patients undergoing the Allen fasting treatment and subsequent low diet. None of these researches, however, gave definite evidence of a low metabolism except those carried out under the somewhat abnormal conditions of a complete fast and severe diabetes.

While the regular accumulation of experimental data regarding basal metabolism has proceeded unabated, the establishment or the discovery of subnormal metabolism was less accentuated since only negative results had previously been obtained. Recently, however, international complications, causing great food stringency in different parts of the war region, have again called our attention to the problem of low metabolism and undernutrition.

The tremendous efforts of the Central Powers of Europe to withstand the food blockades of their opponents resulted in a most surprising development of food substitutes, many of these being prepared from materials formerly used for stock feeding. A complete economic system was thus developed to secure the proper distribution and rationing of the various food materials. Notwithstanding this use of unusual foodstuffs, the rations of the civilian population of Germany were severely curtailed. Most of the early information as to dietetic conditions in Germany, which can be considered as having scientific merit, was brought to this country by Professor Alonzo E. Taylor, formerly assigned to the United States embassy in Berlin. The statistical evidence which he secured in Berlin through his office, by the cooperation of Dr. E. Rost of the Gesundheitsamt and of Professor Rubner, and from innumerable ration cards, shows that the Central Powers as a whole were compelled, on account of war conditions, to adopt a materially lowered ration. This gigantic experiment proves conclusively that such changes are not only possible, but are not necessarily cataclysmic. They therefore challenge the scientific world for explanation.

As compensatory consequences of ration curtailment, only a general loss in body-weight is reasonably demonstrated. Statistically this hardly seems proportional to the diet curtailment, and evidence regarding a possible general reduction in physical activity is absent.

Furthermore, there is lacking that careful scientific balance which is necessary to demonstrate an actual lowering of the metabolism to compensate, in part at least, for the lower food-intake. It appeared to us that if the German civilian population had found it possible under war conditions to subsist on these low rations and had apparently adjusted themselves to an entirely new and heretofore practically unrecognized nutritional level, the scientific foundation for this change was certainly worthy of exact study. Furthermore, such research seemed especially timely, as the attention of a large number of American people was, in 1917, directed towards the conservation of food; it was accordingly important to analyze critically the factors that play the chief rôle in such conservation. Strenuous efforts had been made to reduce the consumption of certain food materials, such as sugar, wheat products, and animal products, by advocating the substitution of other materials, but one factor had previously been for the most part neglected, *i. e.*, the possibility of a reduction in the amount of food consumed. The general problem of reducing the total food consumption quantitatively could not, however, be seriously considered by the laity. In view of the emergency confronting this nation in 1917, it was natural that the importance of food conservation should likewise occupy the minds of practically all physiologists. The question therefore arose with the Nutrition Laboratory: Is it possible by any dietetic régime to lower the total amount of food consumed and not at the same time disproportionately lower efficiency for either intellectual or muscular activity? In other words, is it possible to make a dietetic alteration of material moment which will still enable individuals to carry on their general activities, both intellectually and physically, as members of society, without appreciable detriment?

It has not been the custom of the Nutrition Laboratory to direct its researches primarily for economic and sociological purposes; yet in view of its long-continued study of people with a low intake of food and conceivably low metabolism, and the not remote possibility that America might be obliged to undergo privations similar to those in Germany, although probably in less degree, it seemed eminently fitting for the Laboratory to study a question so important from the standpoints of patriotism, economy, and physiology, as the effect upon the metabolism of a reduction in diet. The extensive research which is reported in this publication is, in the last analysis, a furthering of the initial problem studied by the Nutrition Laboratory, *i. e.*, a search for conditions resulting in subnormal metabolism. It was planned in detail in the spring of 1917 and carried out during the winter of 1917–18 with a selected group of normal individuals whose body-weight was lowered as a result of quantitative reductions in their diet.

Before giving the details and discussing the results of this research, a general history will be given of the experimental work leading up to the present study, together with brief abstracts and a critique of the work of other investigators on metabolism with a low intake of food.

## SEARCH FOR SUBNORMAL METABOLISM.

The initial experiments in the study of variations in basal metabolism were carried out at Wesleyan University, Middletown, Connecticut, with several subjects who seemed to show potentialities for low metabolism. The first study was that of a man who had but one lung,[1] the assumption being made that with diminished lung area there might be distinctly different metabolic activity. The results of this experiment, although perhaps somewhat open to debate when judged by modern technique and compared with modern data, indicated no striking change in the level of metabolism.

From time to time during the past two decades certain individuals, particularly those who have given more than ordinary attention to their dietetic habits, have come forward with the contention that they were able to subsist upon considerably less food than is required by the normal individual. The first one studied was the case of the late Mr. Horace Fletcher. Mr. Fletcher had interested himself in sociological and economic problems for a number of years and had brought himself to believe that by means of a peculiar adjustment of diet and particularly a supposedly advantageous method of excessive mastication, he could subsist upon materially lower amounts of food and with a much lower metabolism than normal individuals. His contention was seemingly supported by the observations of Professor Chittenden,[2] of Yale University. While the observations on Mr. Fletcher dealt primarily with the total nitrogen metabolism, Professor Chittenden, in commenting upon the excessive muscular work done, makes the following statement regarding the energy transformation:

"Yet the work was done without apparently drawing upon any reserve the body may have possessed. The diet, small though it was, and with only half the accepted requirement in fuel value, still sufficed to furnish the requisite energy. The work was accomplished with perfect ease, without strain, without the usual resultant lameness, without taxing the heart or lungs, and without loss of body-weight. In other words, in Mr. Fletcher's case at least, the body machinery was kept in perfect fitness without the consumption of any such quantities of fuel as has generally been considered necessary."[3]

In other words, on the low energy intake of approximately 1,700 calories Mr. Fletcher, carrying out the training régime and exercises of the Yale University crew, was able to perform a day's duty of this type with supposedly no draft upon body material.

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[1] Carpenter and Benedict, Am. Journ. Physiol., 1909, **23**, p. 412.
[2] Chittenden, Pop. Sci. Monthly, 1903, **63**, p. 130; ibid., 1907, **71**, p. 536.
[3] Chittenden, Pop. Sci. Monthly, 1903, **63**, p. 130.

Mr. Fletcher was also studied in 1903 for three successive days inside the respiration calorimeter at Wesleyan University.[1] While his daily activities were necessarily somewhat restricted by the confines of the respiration chamber, a careful record of the movements, hours of sleep, etc., and analyses of both intake and output in terms of chemical elements and of heat showed that the energy transformations of Mr. Fletcher were in no wise different from those of normal individuals. With present-day knowledge of the factors influencing metabolism, we may say, however, that probably Mr. Fletcher's age at that time (54 years) must have played a slight rôle. Here again, therefore, the search for a materially lowered metabolism was unavailing.

Another prominent food investigator studied was Dr. J. H. Kellogg, who has given not a little attention to his own diet, and whose interest and activity in dietetic régimes are well known throughout this country. Subsisting upon a vegetarian diet for many years and particularly on a low protein diet, Dr. Kellogg was convinced that he lived upon a very much lower metabolic plane than the normal individual. This was set forth in a letter published by Mr. Fletcher,[2] from which one infers that Dr. Kellogg believed he subsisted upon approximately 1,200 calories per day. Dr. Kellogg kindly consented to enter the respiration chamber for an experiment comprising several short periods at Wesleyan University in 1906.[3] We were thus able to measure his metabolism when he was asleep, sitting, standing, and walking. From these measurements the probable food requirement was computed. A minimum estimate showed a daily requirement of not less than 2,000 calories. Since the body-weight of Dr. Kellogg was 56.1 kilograms, we thus have a metabolism that is not appreciably lower than that of other individuals, although here again the age factor undoubtedly played some slight rôle.

Another subject who had given special attention to dietetic matters, Dr. M. Hindhede of Copenhagen, was a visitor at the Nutrition Laboratory for a short time in 1910. Although observations could not be made with him according to the strictest basal requirements, nevertheless the metabolism was determined in two or three respiration calorimeter experiments. Although he had presumably been subsisting for several years upon an extraordinarily low-protein and vegetarian diet, his metabolism as measured was not sufficiently low to indicate that his metabolic level was different from that of normal individuals.[4]

The experiment made with Mr. Fletcher at Wesleyan University in 1903 was supplemented by an experiment of only 4 periods at the Nutrition Laboratory in 1912. This was carried out under strictly

[1] Benedict and Milner, U. S. Dept. Agr., Office Exp. Sta. Bull. 175, 1907, p. 199.
[2] Fletcher, The A. B.-Z. of our own nutrition, New York, 1903, p. xxxiii.
[3] Benedict and Carpenter, Carnegie Inst. Wash. Pub. No. 126, 1910, pp. 75 and 96.
[4] Benedict and Carpenter, Carnegie Inst. Wash. Pub. No. 261, 1918, pp. 191 and 192.

basal conditions, and reported by Benedict, Emmes, Roth, and Smith, in their summary of metabolism measurements for 89 men and 68 women.[1] At this time Mr. Fletcher was 63 years old and appreciably over-weight, having a body-weight without clothing of 82.1 kg., with a height of 166 cm. The measurements of the metabolism gave a heat production of 19.7 calories per kilogram of body-weight per 24 hours. This is materially different from the average of 25.5 calories for the whole group of 89 men and, in fact, is lower than that for any other individual in the group. The nearest approach to this value was found with Professor Otto Cohnheim, who visited the Laboratory at about this time. With an age of 36 years, a body-weight of 83 kg., and a height of 169 cm., Professor Cohnheim (in 12 observations on 3 days) gave a heat production of 19.9 calories per kilogram and per 24 hours. Although Professor Cohnheim was much younger than Mr. Fletcher, of a highly nervous temperament in contrast to the phlegmatic temperament of the latter, and also a liberal meat-eater, the differences in age, temperament, and dietetic habits were more than counterbalanced by the decided overweight of the two men. It is evident that this excess body-weight and adipose tissue had an effect upon the heat production per kilogram of body-weight of both men. Nevertheless the fact remains that the value for Mr. Fletcher of 19.7 calories is the absolute minimum for values obtained with 89 men reported in 1914.

Zuntz and Schirokich[2] report a series of observations made with Mr. Fletcher about three months previous to the experiment at the Nutrition Laboratory, *i. e.*, in February and March, 1912. The Zuntz-Geppert apparatus was used. The investigators conclude that the basal metabolism of this man was on a low plane which was coincidental with a restricted and protein-poor diet, for the subject had been living for 3 months on a diet of potatoes and butter. The post-absorptive values showed a low output of approximately 19 calories per kilogram per 24 hours. As Zuntz and Schirokich point out, this agrees very well with the values found in the respiration calorimeter at Wesleyan University with young men fasting and at rest. The two fasting men studied in the Zuntz laboratory, Cetti and Breithaupt, showed a higher basal metabolism of from 29 calories with Cetti to 24 calories with Breithaupt. While the Fletcher values are complicated by the factors of age and weight, the experiments distinctly suggest a lower metabolism with a low nitrogen intake. Although Zuntz speaks of the diet as being restricted, the caloric intake of 2,750 calories in the first period should certainly be sufficient to cover the needs of the subject. In the second period the caloric intake of 2,116 calories is probably somewhat less than the actual requirements of the body.

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[1] Benedict, Emmes, Roth, and Smith, Journ. Biol. Chem., 1914, 18, p. 139.

[2] Zuntz and Schirokich, Separate from Med. Klinik, 1912, No. 32, 5 pp.

Since the metabolism of Mr. Fletcher has been a matter of unusual interest, the results thus far obtained with him are summarized in table 1, these including the early observations at Wesleyan University in 1903, the observations made by Zuntz and Schirokich in February and March, 1912, and those made at the Nutrition Laboratory in May of the same year.

TABLE 1.—*Basal metabolism of Horace Fletcher (lying).*

| Date. | Age. | Body-weight without clothing. | Height. | Body-surface.[1] | Observation. | | Heat. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Days. | Periods. | Per 24 hours. | Per kilogram per 24 hours. | Per square meter per hour.[1] |
| | *yrs.* | *kilos.* | *cm.* | *sq. m.* | | | *cals.* | *cals.* | *cals.* |
| Nov. 10–13, 1903[2].. | 54 | 71.6 | 168 | 1.81 | 3 | 3 | 1610 | 22.5 | 37.1 |
| Feb. 16–21, 1912[3].. | 63 | ca. 76.0 | 166 | 1.84 | 3 | 6 | 1458 | 19.2 | 33.0 |
| Mar. 8–16, 1912[3].. | 63 | 76.1 | 166 | 1.84 | 6 | 12 | 1471 | 19.3 | 33.3 |
| May 7, 1912[4].. | 63 | 82.1 | 166 | 1.90 | 1 | 4 | 1615 | 19.7 | 35.4 |

[1] Body-surface computed from height-weight chart of Du Bois. Arch. Intern. Med., 1916, **17**, p. 863.

[2] Benedict and Milner, U. S. Dept. Agr., Office Exp. Stas. Bul. 175, 1907, pp. 51, 84, and 199. Values obtained between 1 a. m. and 7 a. m. Strictly speaking, subject not in post-absorptive condition, as a predominatingly carbohydrate supper, containing about 500 calories, was eaten at 7 p. m.

[3] Zuntz and Schirokich, Separate from Med. Klinik, 1912, No. 32, 5 pp. Subject had been living on a continued scanty protein-poor diet (potato and butter).

[4] Benedict, Emmes, Roth, and Smith, Journ. Biol. Chem., 1914, **18**, p. 142.

While unquestionably during the study of Zuntz and Schirokich the subject was living on a scanty protein-poor diet and had been for some time, we have no positive information as to his dietetic habits during May of 1912, when he was studied at the Nutrition Laboratory. From the body-weight in May one would be inclined to think that he had been living upon a rather liberal diet, the weight being 82.1 kg. as compared with 76 kg. in February and March. Nine years before (in 1903), when the body-weight was 71.6 kg., the metabolism as determined at Wesleyan University was distinctly higher. It is clear, therefore, that the evidence presented by Mr. Fletcher may not be taken alone as indication of a reduced metabolism resulting from chronic undernutrition. While there is no doubt that the protein intake during a considerable period of time may have been low, the fluctuations in body-weight indicate somewhat wide variations in the dietetic habits of this subject as to the energy intake.

In the 1903 study, in the selected period between 1 and 7 a. m., when the subject was in bed inside the respiration calorimeter and without food, we find that the heat production per kilogram of body-weight was

22.5 calories with a body-weight of 71.6 kg. Nine years later, in 1912, when he was studied in February and March by Zuntz and Schirokich, and in May at the Nutrition Laboratory, the values obtained per kilogram of body-weight were 19.2, 19.3, and 19.7 calories. His basal metabolism at or about this time was thus a little over 19 calories per kilogram per 24 hours, which is distinctly low. Two factors, however, have an important bearing here. One is obesity, for, with a height of 166 cm. and an age of 63 years, the normal weight would be 65 kg.,[1] while Mr. Fletcher's weight ranged from 76 to 82 kg. The excessive adipose tissue would tend to lower the heat production per kilogram. Secondly, the element of age should be considered, for, as has been shown by practically all the observations thus far available, with advancing years there is a definite tendency to a lowering of the metabolism. While, therefore, Mr. Fletcher's metabolism was distinctly lower than the normal average, it is by no means evident that this was due in any part to dietetic habits or to any other known factor than those of age and obesity.

The nitrogen output has a special interest in this connection when considered as an index of the level of the protein katabolism. The data for the nitrogen output for most of these subjects with presumably low metabolism have been collected in table 2, which shows that Prof. C.

TABLE 2.—*Nitrogen excretion of subjects studied for low metabolism.*
(Subjects post-absorptive.)

| Subject. | Nitrogen excretion per kilo. per hour. | Date. | Literature references. |
|---|---|---|---|
| | *mg.* | | |
| Prof. C* | [1]8.3 | Nov. 17, 20, 22, 1909. | [1] Benedict and Joslin, Carnegie Inst. Wash. Pub. No. 136, 1910, p. 196. |
| H. F... | [1]5.6 | Nov. 19, 1909. | [2] From unpublished material at Nutrition Laboratory. |
| H. F... | [2]4.5 | May 7, 1912. | [3] Based on per 24 hour determinations; subject not post-absorptive but on a low nitrogen diet. Zuntz and Schirokich, Separate from Med. Klinik, 1912, No. 32, 5 pp. |
| H. F... | [3]2.5 | Feb. and Mar., 1912. | [4] Benedict and Carpenter, Carnegie Inst. Wash. Pub. No. 261, 1918, pp. 177, 191, and 192. |
| Dr. H.. | [4]5.0 | Feb. 14, 1910. | |
| Dr. H.. | [4]4.6 | Feb. 17, 1910. | |

* Introduced for comparison.

has a nitrogen excretion per kilogram per hour of 8.3 mg. This is somewhat higher than the average found for 10 subjects, including Prof. C. and H. F., and reported by Benedict and Joslin,[2] the average for all subjects being 6.85 mg. On the other hand, both Dr. H. and H. F. show a low nitrogen excretion, the average of two experiments

[1] Computed from table 4, Medico-Actuarial Mortality Inv., New York, 1912, 1, p. 38, deducting 8 lbs. for clothing.
[2] Benedict and Joslin, Carnegie Inst. Wash. Pub. No. 136, 1910, p. 196.

with Dr. H. being 4.8 mg. and the three values found for H. F. being 5.6, 4.5, and 2.5 mg. No post-absorptive nitrogen figures are available for Dr. Kellogg. It is clear, however, that Prof. C. was excreting nearly twice as much nitrogen as the other subjects and hence was on a fairly high nitrogen level. The fact that his metabolism per kilogram of body-weight was so low—but 0.2 calorie higher than that of H. F. or 19.9 calories as compared with 19.7 calories—must in all probability be due solely to excess body fat. Both subjects were distinctly over-weight and showed low metabolism per kilogram of body-weight.

It thus appears that a critical examination of the metabolism data for these individuals with supposedly low metabolism does not show appreciable deviations from the normal. With a rare pathological case there may be justification for laying weight upon the metabolism of a single individual, but the Nutrition Laboratory has, in recent years, strongly opposed the use of such individual data for comparison. Furthermore we have strenuously objected to an undue use of a so-called "standard" figure for the metabolism, as we believe that individual variations may be so great as to render these individual comparisons practically valueless. Hence, while the evidence for both Mr. Fletcher and Dr. Kellogg, and particularly the latter, did not indicate a noticeably low metabolism due to dietetic habits, it seemed best to study the question with groups of individuals, since with these only can convincing data be obtained.

With the idea that a vegetarian diet, which might be assumed to be likewise a low-protein diet, would result in a low metabolism, a series of investigations was carried out with approved technique at the Battle Creek Sanitarium, by Benedict and Roth (Journ. Biol. Chem., 1915, **20**, p. 231). Through the courtesy of Dr. Kellogg, a large number of men and women vegetarians were thus studied. It became clear to us at this time that the so-called group system of comparison was absolutely necessary, namely, that only individuals of like height and weight may properly be compared. Hence for comparison with the men and women vegetarians we selected a group of normals, *i. e.*, non-vegetarians, of like weight and height. The vegetarians, even with a presumably low nitrogen output and a less stimulated plane of metabolism due to the lowered nitrogen metabolism, did not have a lower total metabolism than the individuals subsisting on a mixed diet.

In an analysis of the results obtained with some 150 individuals[1] it was found not only that, strictly speaking, there is no constancy in the basal metabolism, but also that those instances in which the metabolism is low give no indication of a general picture of unusually low metabolism due to other than well-known causes. In consideration of the fact that sex, age, muscular training, and body composition (*i. e.*, proportion of inert body-fat and active protoplasmic tissue), height in

[1] Benedict, Journ. Biol. Chem., 1915, **20**, p. 263.

individuals of the same weight and age, sleep, and the after effect of exercise, all have an influence upon the basal metabolism, the conclusion was drawn that the basal metabolism of an individual is a function, first, of the total mass of active protoplasmic tissue and, second, of the stimulus to cellular activity existing at the time the measurement of the metabolism was made. It was furthermore maintained that "apparently at present no law can be laid down that will cover both of these important variables in the basal metabolism of an individual."[1]

## STUDY OF FACTORS TENDING TO LOWER METABOLISM.

In our study of variations in basal metabolism, special consideration has been given to the question of those factors which tend to lower the metabolism, and it was early recognized that prolonged fasting produced such an effect. The results obtained at the Nutrition Laboratory during the 31-day fasting experiment[2] on the subject L. are decisive on this point. Here the analysis was first made upon the basis of per kilogram of body-weight and per square meter of body-surface; the body-surface was computed by the old formula of Meeh. By both methods of computation, definite loss in heat production was found as the fast progressed, save that after the fourteenth or fifteenth day there was a tendency to constancy. A subsequent revision of the calculations of body-surface, based upon a series of photographs and the more modern Du Bois measurements,[3] confirmed the earlier findings and placed them upon a more scientific basis.

A somewhat complex factor entered into the interpretation of the values for the basal metabolism of this fasting man in that a definite acidosis developed. Although we believe that acidosis tends to stimulate the metabolism and thus would partly offset the depressing effect of the fasting *per se*, nevertheless there is no question but that the metabolism per kilogram of body-weight or per square meter of body-surface was distinctly lowered as a result of fasting. Of particular significance is the fact that with this fasting man there was no proportionate loss of strength but a general feeling of unimpaired mental and physical activity. While the subject showed a falling off in the dynamometric tests, from a superficial observation one would never realize that the man had been without food for 31 days. In talking to a group of medical men on the thirty-first day of his fast, he exhibited all the vivacity, strength of voice, and vigor of gesture that an ordinary individual would use. We thus have here evidence of a depressed metabolism unaccompanied by marked loss in intellectual or physical powers. It was demonstrated, therefore, that a specific factor, namely, complete inanition, can produce a definite and thoroughly established lowering of metabolism.

[1] Benedict, Journ. Biol. Chem., 1915, **20**, p. 299.
[2] Benedict, Carnegie Inst. Wash. Pub. No. 203, 1915.
[3] Benedict, Am. Journ. Physiol., 1916, **41**, p. 292.

The next evidence obtained in the Nutrition Laboratory of a pronounced decrease in the metabolism was the metabolic condition subsequent to the Allen fasting treatment for diabetes. In an extensive series of observations on metabolism in diabetes made in this Laboratory in conjunction with Dr. Elliott P. Joslin, cases of severe diabetes of the acid type showed high metabolism when compared with groups of normal individuals of like height and weight. After a few days' fasting under the remarkable Allen fasting treatment, the acidosis disappeared and the previously existing high metabolism was followed by a striking decrease in metabolism to far below that of the controls. This fall in the metabolism was found in so many cases that it may be considered as thoroughly established. It was subsequently verified by Du Bois in direct calorimetric observations. It may naturally be inferred that the cases of severe diabetes represent extreme emaciation or inanition, and hence it is appropriate to compare them with the man who fasted 31 days. From the diet charts of these patients after the Allen fasting treatment we find surprisingly low food-intakes. Yet these individuals are not moribund; they are able to be about the hospital, perform their own urinary tests, attend conferences, and engage in exercise even to the extent of walking 3 or 4 miles per day. While not rugged, they are by no means confined to bed, and yet they show this extraordinarily low basal metabolism. It appears, therefore, that with great loss of flesh there is a distinctly lower basal metabolism. We accordingly have here a second clear index of a lower metabolic level.

As a result of this long study of variations in basal metabolism and the factors which depress metabolism, we thus found a lower basal level only during fasting and with diabetics subsequent to the Allen fasting treatment. Since our earlier researches produced such negative results, it is incumbent upon us to examine previous studies interpreted as signifying a depressed metabolism due to undernutrition or other conditions and to present a critique of the results obtained.

## PREVIOUS INVESTIGATIONS ON METABOLISM WITH UNDERNUTRITION.

Many of the researches on undernutrition in the earlier literature were made with animals, and some were carried out under pathological conditions. In collecting data regarding the previous investigations on undernutrition, the studies dealing solely with the loss of nitrogen have been purposely omitted, for only in rare instances have there been satisfactory determinations of the balance of nitrogen intake and output for indicating a true gain or loss to the body. The total nitrogen outgo, *i. e.*, the nitrogen in the urine and feces, may be accurately determined without extraordinary analytical procedure, but this tells only half the story and must be supplemented by data regarding the intake. The difficulty of sampling and analyzing mixed diets to secure the total nitrogen of intake is obvious; computed values have, at best, but little significance. Moreover, the nitrogen data are in many of the studies complicated by distinct pathological conditions, thus excluding them from special consideration in a study of the influence of undernutrition on normal healthy people. It seems best, therefore, to disregard the literature bearing upon the subject of the loss of nitrogen due to undernutrition and to confine the discussion of the previous findings solely to the influence of undernutrition upon the gaseous metabolism.

*Pettenkofer and Voit, 1871.*—The importance of studying animals in different stages of nutrition was early recognized by Pettenkofer and Voit,[1] who made observations in which 500 to 2,500 grams of meat were fed daily to a dog weighing approximately 35 kg. The smaller portion of food, which corresponds more specifically to undernutrition, was continued for approximately 6 weeks. At first sight it appears as if an experiment of this type would throw definite light upon the demands of the body while on a low nutritional plane. The experimental technique, however, which unfortunately was followed by a number of later observers, involved feeding the animal with meat, placing it at once inside the respiration chamber, and then making observations on the respiratory products in 24-hour periods. It is to be regretted that the excellent method frequently employed by Pettenkofer and Voit of separating their experimental period into day and night periods was not here used, for it is undoubtedly true that during the first hours of the day the metabolism was greatly stimulated by the ingestion of meat, the stimulation being approximately proportional to the amounts of meat ingested. The metabolism as measured, therefore, was not basal metabolism, but basal metabolism plus the stimulus of meat. The authors note that there was a distinct falling off in the metabolism when the smaller quantities of meat were given, 500 grams of meat

[1] Pettenkofer and Voit, Zeitschr. f. Biol., 1871, 7, p. 433.

representing scarcely half the dog's requirements. While Pettenkofer and Voit have not specifically discussed in detail the undernutritional stage of this series of experiments, their data are referred to and in a certain sense recalculated by Rubner.[1] In discussing these and some other experiments Rubner recognizes that, in addition to the loss in body substance produced by acute or prolonged hunger, the heat-production usually decreases in proportion to the decrease in mass, but points out the possibility of individuality. In Pettenkofer and Voit's experiments, while there was no measurable loss in carbon-dioxide excretion per kilogram of body-weight during the period of undernutrition, in which the body-weight varied from 34.4 to 30.0 kg., there was a much greater heat-production, as measured by the carbon-dioxide output, with a diet of 1,500 grams of meat than with 1,000 grams. The fact that the actual basal metabolism was not measured makes it difficult to interpret these experiments as evidence of a decrease in the basal metabolism due to undernutrition.

*Klemperer, 1889.*—Although based primarily upon nitrogen measurements and body-weight rather than upon the metabolism, Klemperer's[2] conception of the adjustment of the body to high or low diets is the first clearly formulated. In his celebrated experiment on a tailoress, Klemperer, arguing from the fact that body nitrogen was in equilibrium and that consequently the calories must have been in equilibrium, maintained that this individual could, when resting in bed, subsist upon 18 calories per kilogram per 24 hours. Both experiment and conclusion have been adversely criticized by von Noorden,[3] but Klemperer was the first to indicate "die Möglichkeit und Wahrscheinlichkeit verringerten Energieumsatzes" or "die Lehre von der Anpassung des Umsatzes an die gereichte Kost."[4]

*Lehmann, Mueller, Munk, Senator, and Zuntz, 1893.*—The classic experiments made by Lehmann, Mueller, Munk, Senator, and Zuntz[5] on two fasting men must be interpreted in the light of the present day knowledge of the influence of fasting upon metabolism. Zuntz and Lehmann concluded, because the heat production of the subject Breithaupt after the fast was less, even with a larger diet, than before the fast (24.8 as compared with 27.3 calories per kilogram per 24 hours), that with certain conditions the undernourished body may use foodstuffs more economically than a well-nourished body, but emphasize the fact that further information is desirable. We now know that fasting *per se* depresses the metabolism. The ingestion of food first offsets this depression, then stimulates the metabolism to higher

[1] Rubner, Gesetze des Energieverbrauchs bei der Ernährung, Leipsic, 1902, pp. 296–297.
[2] Klemperer, Zeitschr. f. klin. Med., 1889, **16**, p. 597.
[3] von Noorden, Metabolism and practical medicine, **2**, Pathology, Chicago, 1907, foot-note 1, p. 5.
[4] Magnus-Levy, Zeitschr. f. klin. Med., 1906, **60**, p. 203.
[5] Lehmann, Mueller, Munk, Senator, and Zuntz, Arch. f. path. Anat. u. Physiol., 1893, **131**, Supphft., p. 1.

activity; hence these experiments are not clear evidence on undernutrition and serve only to point out the error of using the last day of fasting for a base-line.

*Russian research on undernutrition: V. V. Pashutin, Albitsky, and I. A. Pashutin, 1887–1902.*—While prolonged fasting and complete starvation have received experimental attention in a great many physiological laboratories, surprisingly little attention has been paid to chronic undernutrition, except in Russia. Russians fast frequently during the year and chronic undernutrition is common among the poor classes. It is probable, however, that in the religious fasting seasons the Russians do not fast in the strictest sense of the word, as they are said to continue their work with apparent vigor and sustained vitality, although they lose in weight, indicating that the nutrition must be insufficient.[1] As a result of the frequent occurrence of incomplete nutrition among the Russian people, we find that the metabolism during undernutrition was studied in the laboratory of Professor V. V. Pashutin by Albitsky and later by I. A. Pashutin. In these well-planned investigations studies were made of the metabolism of animals during insufficient feeding and subsequent realimentation.

The series of experiments made by Albitsky was extensively discussed by the senior Pashutin in his course on general and experimental pathology.[2] The experiments made by the younger Pashutin are reported in a dissertation published in 1895, which gives one of the best general discussions of undernutrition printed as early as that date.[3] In this dissertation Pashutin raises the question as to whether the vital processes would be affected if the normal diet were reduced one-fourth, one-third, or one-half.

The primary object of Albitsky's experiments was to study the influence of repeated periods of complete fasting (with or without water) and subsequent realimentation. One of the tables in Pashutin's book shows the carbon-dioxide excretion and oxygen consumption for Albitsky's rabbit No. 4, in four successive fasts, and the first and third realimentation periods. For comparison, the table also gives an average normal value which was determined during 4 days of normal feeding prior to the third fasting period. Unfortunately no normal value for the gaseous exchange, either in the post-absorptive state or with food, was obtained before the beginning of the first fasting period. During the first few days of the first and third realimentation periods, the rabbit, confined in the Pashutin respiration chamber, received food for only a few hours daily. Since it is the custom of these animals to eat

[1] I. A. Pashutin, The metabolism of animals during insufficient feeding and subsequent realimentation. Diss., St. Petersburg, 1895. See introduction.

[2] V. V. Pashutin, General and experimental pathology (Pathological Physiology), St. Petersburg, 1902, 2 (1), p. 177 (Russian). So far as we know, the full details of these experiments are given in no other place, although mention is made of the fact that the experiments were published in part in the report of a convention in Moscow in 1887.

[3] I. A. Pashutin, loc. cit.

intermittently the greater part of the 24 hours, the rabbit received an insufficient amount of food on these first days, the intake being roughly proportional to the length of time in which the rabbit had access to food. The values obtained during these realimentation periods supply the only data which have an interest in our discussion of the influence of undernutrition.

In the first 3 days of the first realimentation period, the solid matter eaten was but 13, 34, and 36 per cent, respectively, of the amount eaten during the normal period; on the corresponding days in the third realimentation period, it was 62, 49, and 33 per cent, respectively. Since the intake of solid material did not reach the normal amount until the seventh day in the first realimentation period and the sixth day in the third realimentation period, the animal was distinctly undernourished in the earlier days of these periods. On the first day of the first realimentation period, the oxygen consumption per kilogram of body-weight per 24 hours was a little more than one-half the normal value (15.81 grams as compared with 27.58 grams). In the third realimentation period, the oxygen consumption for the first day was 25.08 grams. The carbon-dioxide excretion on the first days of these realimentation periods was 17.79 and 32.16 grams, respectively, and thus much lower than the normal value of 42.41 grams. The oxygen consumption and carbon-dioxide excretion, particularly in the third period, did not return to normal until the food intake was essentially that prior to fasting. During these two periods of undernutrition, therefore, the metabolism per kilogram of body-weight was considerably lower than normal, the oxygen being from 43 to 9 per cent less and the carbon dioxide from 58 to 15 per cent less in the first and third realimentation periods, respectively. While the difference in the carbon-dioxide excretion may naturally be accounted for, in part, by the difference in character of the carbonaceous material in the food, the values would indicate that during chronic undernutrition there is at first a distinct lowering of the metabolism per kilogram of body-weight when measured by either the oxygen consumption or the carbon-dioxide excretion, as compared with the metabolism with a normal amount of food. The fact, however, that the oxygen consumption increases from 43 to only 9 per cent below normal in the third realimentation period would indicate that with the larger diet in the third period the metabolism immediately tended to follow the higher plane of nutrition.

This finding is substantiated by a comparison of the metabolism during the realimentation periods with the metabolism on the first days of the first fasting period, for, aside from the expected increase in metabolism due to the influence of the ingestion of food, Albitsky reports that the intensity of metabolism, even with an insufficient amount of food, was greater in the later realimentation period as compared with the earlier. Albitsky's whole conception, however, is com-

plicated by the fact that considerably larger quantities of food were taken during the third realimentation period. It is interesting to note in this connection that the statement is made that on account of this greater intensity of metabolism which was accompanied, at least in some experiments, by a high temperature,[1] the animal in the realimentation period should eat from 1 to 1.5 times as much food as would be taken normally and drink twice as much water to regain the weight lost in fasting.

While it should be borne in mind that Albitsky's observations on realimentation and metabolism during undernutrition were incidental to the major study, continuing only 3 or 4 days, and the deductions are thus based upon fragmentary evidence, his final conclusions are that, during realimentation with a diet below maintenance, the metabolism per kilogram of body-weight was at first distinctly lower than normal, but as the undernutrition continued, the metabolism gained in intensity till it more nearly approached the normal. These conclusions are distinctly open to question on account of changes in the amount of food administered during the compared periods.

In contradistinction to Albitsky's conclusions, a statement is made in the dissertation of the younger Pashutin[2] that a full-grown rabbit, well fed and in a condition of equilibrium, when gradually deprived of 25 to 50 per cent of its food and the low nutrition continued for some time, showed but little change in the vital processes and general health, so far as could be judged by the body-weight. This paradoxical phenomenon of the actual change in the metabolism of animals under such conditions of reduced diet was confirmed by the younger Pashutin's later study in the same laboratory. An apparatus on the closed-circuit principle, devised by Professor V. V. Pashutin, was used for measuring the carbon-dioxide excretion and the oxygen consumption.

In this study, rabbits and subsequently dogs were employed. The plan was ingenious in that the amount of nutriment required for maintenance was first determined and then a certain percentage of the food was gradually withdrawn. The attempt was made in the undernutrition period so to adjust the diet that the loss in body-weight should be less than 15 per cent. This was done on the supposition that degenerative changes in the organs and tissues would appear with a 15 per cent loss in weight or, according to one Russian observer, Okhotin, with a 10 per cent loss. Although the food of the first rabbit was reduced to 85 per cent of the normal requirement, the total carbon-dioxide excretion and oxygen consumption did not change or at least did not exceed normal fluctuations. Since the body-weight of this particular rabbit fell only 6 per cent, it is probable that no definite conclusions can be drawn from the data. With a second rabbit the

[1] Another Russian writer, Manassein (Medical Information, 1871), in experiments with animals with complete starvation, also noted a high temperature, which he characterized as febrile.

[2] I. A. Pashutin, loc. cit.

food was reduced to 67 per cent of the normal needs and the body-weight fell 11 per cent. As a result of these experiments with rabbits, it appeared perfectly possible to reduce the diet considerably with almost inappreciable alteration in the total oxygen consumption. Since the curtailment in diet produced only slow changes in the body-weight and since, in the absence of evidence as to the activity of the animal under observation, it must be assumed that the activity was relatively constant, it follows that the lowered food intake was without appreciable effect upon the metabolism.

In experiments with dogs, Pashutin found that when the diet was reduced to 75 per cent of the normal requirement, neither the oxygen consumption nor carbon-dioxide production was appreciably altered. On the other hand, the period of observation was so short (apparently not far from 2 weeks) that the diet was not sufficiently low to alter materially the body-weight.

A dog, with which observations were begun January 15, was fed for a month with 500 grams of horse flesh daily. Its weight in the middle of February was 6,098 grams. The food was then reduced and 75 per cent of the normal diet given for 19 days, 65 per cent for 29 days, and 55 per cent for 7 days. During the last period the animal fell to a weight 10.6 per cent below the initial weight. He was subsequently fed with 500 grams of meat for 24 days; a second undernutrition period of 33 days with 55 per cent of food followed. Under these conditions it was found that when 75 per cent of food was given, the oxygen consumption and carbon-dioxide excretion fell to about 88 per cent of the normal; it was not until the food was reduced to 55 per cent of the normal diet that the gaseous metabolism fell to approximately 75 per cent. In the realimentation period the gaseous metabolism did not return to the normal amount. In the second undernutrition period the oxygen fell to 71 per cent and the carbon dioxide to 66 per cent of the normal excretion. During the second realimentation period of 23 days with 500 grams of meat the animal gained in weight so that he was 26 per cent above normal. Even under these conditions the oxygen consumption was only 79 per cent of normal and the carbon-dioxide production 74 per cent. With this dog, therefore, it is clear that the reduction in diet was accompanied by a distinct fall in the respiratory exchange, a fall that was not compensated by realimentation, even when the body-weight increased to 26 per cent above normal.

A second dog was brought into equilibrium at a body-weight of 6,221 grams by feeding with an abundance (617 grams) of horse flesh. The food was then reduced to 63.2 per cent of his normal amount. This period of undernutrition continued 23 days. The dog was next fed for 28 days with approximately 3 per cent above the normal amount of food. A second undernutrition period of 22 days followed, in which the food

was again reduced to 63.2 per cent. As during the realimentation period the animal had gained in weight to more than 20 per cent and even during the second period of lowered food intake it was 17 per cent above weight,[1] the investigator further gradually reduced the food to bring the body-weight to the original point. To do this it was finally necessary to reduce the food to approximately one-third of the normal amount and continue this diet for four weeks. The author concludes from these experiments that the sudden curtailment of food had a much greater effect upon the metabolism than a gradual reduction of food intake. At no period of the realimentation process did the gaseous metabolism exceed normal; in fact, when the food intake was two-thirds that of the normal amount, both the oxygen consumption and carbon-dioxide production approximated 75 to 80 per cent of the normal. During the period of very greatly reduced intake, when the food finally reached but 30 per cent of the maintenance amount, no gaseous metabolism measurements were made.

With a third dog the food was reduced to 50 per cent of normal, the reduction being made at the rate of 1 per cent of the food quantity per day. After the reduction reached 80, 70, 60, and 50 per cent, a 3-day study of the gaseous metabolism was made at each of these points. The whole experiment lasted 87 days. The body-weight at the end of the low feeding was 13 per cent below the initial weight; the gaseous metabolism per kilogram decreased with oxygen to 94.6 per cent and with carbon dioxide to 86 per cent of the initial quantities.

Pashutin points out, with a conservatism which could well be followed by many modern writers, that his conclusions are based upon only two complete experiments in which the metabolism during realimentation was studied, and therefore he ascribes no great value to them. They are, however, at variance with those of Albitsky, who noted an increment in oxidation[2] during the realimentation periods following starvation, while in Pashutin's experiments the chronic undernutrition resulted in a distinct lowering of metabolism per kilogram of body-weight. Even when the maintenance diet was exceeded, the gaseous metabolism did not reach normal, thus indicating a distinct lowering in the plane of metabolic activity.

*Svenson, 1901.*—Svenson,[3] interpreting many observations in the earlier literature as indicating lowered energy requirements with chronic undernutrition, attacked the problem from the standpoint of changes in metabolism during convalescence from typhoid fever or pneumonia. He sought to discover if, during convalescence, there was an attempt made by the organism to economize by reducing oxidation, as he considers is done in chronic undernutrition. Employing the

[1] These conditions seem inexplicable except on the ground that the initial equilibrium weight of 6,221 grams was in reality overweight, and accompanied by excess food intake.
[2] This, we believe, is due in large part to the larger food intake (see page 16).
[3] Svenson, Zeitschr. f. klin. Med., 1901, 43, p. 86.

Zuntz-Geppert apparatus, Svenson found that with typhoid patients in the first period of convalescence and in the *nüchtern* condition, there were for a short time subnormal values for carbon-dioxide production and oxygen consumption, but the values soon increased until they gradually became abnormally high and subsequently fell again to normal values. He concludes that the lowering of the oxidation processes in the first stages of convalescence is not a sign of a definite adjustment of the organism to a lower level, but rather is incidental to the exhaustion of the organism. After long illness the functions of all the organs suffer more or less and the sensitivity of the nervous system is decidedly lowered; but when the subject's organism and the central nervous system have recovered to some degree, exhaustion disappears and gives place to an increase in metabolism. On the whole, his evidence can be interpreted as indicating low metabolism with chronic undernutrition and high metabolism with excess food.

*F. Müller, 1903.*—Friedrich Müller[1] admits that with long-continued undernutrition due to disease or lack of food, a lower body-weight can be maintained with a much smaller intake of food and lower oxidation processes, but nevertheless considers that such decrease of oxidation is small and the cases are exceptional.

*Richter, 1904.*—The small amount of evidence regarding gaseous metabolism obtained in the study of Richter[2] on a patient with esophagus stricture does not lead to clear deductions as to metabolism during excess feeding following emaciation. Although there was a large increase in body-weight and storage of nitrogen, the average values for the respiratory exchange of 4.8 c.c. of oxygen and 3.76 c.c. of carbon dioxide per kilogram per minute, while representing perhaps the higher border of normal values, cannot of themselves be taken as clearly indicating an excess metabolism. The gaseous metabolism measured 3 hours after the ingestion of food showed a normal stimulation from food.

*Magnus-Levy, 1906.*—In his study of the influence of disease on metabolism, Magnus-Levy[3] cites a striking illustration of chronic undernutrition and gives a lengthy series of respiration experiments with this subject at different stages of body-weight. The height was 160 cm. In the first period, when the body-weight was 36.2 kg., the temperature was subnormal, and the oxygen consumption per kilogram per minute was 3.33 c.c. When the body-weight had risen to 38 kg. the oxygen consumption had risen to 4.1 c.c. At 52.2 kg., when the subject was essentially under normal conditions of nutrition, the oxygen consumption was 4.11 c.c. In discussing this most interesting case, Magnus-Levy refers to Klemperer's research in 1889[4] as the first instance in

[1] F. Müller, v. Leyden's Handb. d. Ernährungstherapie, Leipsic, 1903, 1st ed., 1, pp. 195 and 196.
[2] Richter, Berl. klin. Wochenschr., 1904, p. 1271.
[3] Magnus-Levy, Zeitschr. f. klin. Med., 1906, **60**, p. 177.
[4] Klemperer, Zeitschr. f. klin. Med., 1889, **16**, p. 550.

which an adjustment of the metabolism to needs was noted. He points out that this is really the expression of a popular conception of the laity, which is also held by many physicians, *i. e.*, that when the food is diminished there is diminished oxygen consumption, and with excess food there is excess oxygen consumption.

Magnus-Levy finds it impossible to explain the lowered metabolism of his subject on the basis of the body-surface law. We must dissent with him, however, when he states (in italics) that a lowering of the body-weight from 55 to 36 kg. produces an insignificant alteration of the body-surface. According to the height-weight chart of Du Bois, a subject having a height of 160 cm. has a body-surface of 1.31 square meters with a body-weight of 36 kg., but with a body-weight of 55 kg. the body-surface is increased to 1.56 square meters, a difference of approximately 20 per cent. Magnus-Levy is further convinced that in this case there was certainly an adjustment of the metabolism to the food consumption, pointing out that this adjustment continued at the low level only so long as the food intake was very low, and that with the large diet the metabolism immediately tended to follow the higher plane of nutrition. This is one of the clearest cases on record of the adjustment of metabolism to needs. It is somewhat surprising that so little attention has been paid to it in current literature.

*von Noorden, 1906.*—von Noorden's[1] very interesting and suggestive discussion of underfeeding collects the literature on the subject up to the time of publication and shows the singularly deficient evidence with regard to total metabolism as measured by the respiratory exchange under conditions of chronic undernutrition. As von Noorden points out, the experiments on complete withdrawal of food are relatively numerous. These have been supplemented by observations from the Nutrition Laboratory and thus metabolism under complete fasting is fairly well pictured. To what extent the evidence obtained during complete fasting may apply to chronic undernutrition must be considered carefully in this discussion. von Noorden very properly distinguishes between complete starvation and partial undernutrition, but the heat measurements or measurements of the gaseous exchange have rarely been made on conditions other than complete starvation. He points out that Rubner's experiments[2] show that there is a diminishing heat production per kilogram with a progressive loss in weight, but contends that:

"Es muss einstweilen dahingestellt bleiben, ob die bei fortschreitender Abmagerung gelegentlich eintretende Verringerung des Energieumsatzes (pro Kilo) von einer geringeren Lebhaftigkeit der Bewegungen, die mit der Schwächung des Körpers einsetzt, zusammenhängt (Rubner), oder ob das

[1] von Noorden, Handbuch der Pathologie des Stoffwechsels, Berlin, 1906, 2 Aufl., 1; Metabolism and practical medicine, 2, Pathology, pp. 1–61, Chicago, 1907.

[2] Rubner, Die Gesetze des Energieverbrauchs bei der Ernährung, Leipsic, 1902, p. 296.

zersetzende Protoplasma, sich der bedrängten Lage anpassend, sparsamer arbeitet."[1]

*Falta, Grote, and Staehelin, 1907.*—Although the main object of the investigation of Falta, Grote, and Staehelin[2] was to study the specific dynamic effect of individual proteins and the physiological utilization of hydrolyzed protein, certain of their experiments and conclusions have a bearing upon the question of undernutrition. In one series various amounts of meat were fed to a dog weighing approximately 24 kg. The ingenious Jaquet respiration apparatus was employed, but with unfortunately small differences in carbon-dioxide increment and oxygen deficit in the expired air; the errors of gas analysis were therefore greatly magnified. Furthermore, for our purpose of studying the influence of undernutrition, the results are more or less contaminated by the inclusion of the increased metabolism due to the stimulating effect of the meat. Although the experiments are so subdivided as to give measurements in the latter part of the 24 hours, it is questionable whether, when meat was given in large amounts, the entire influence of the food had disappeared even at the end of 24 hours. Several series of experiments were made, each consisting of 3 days. On the first day there was a basal experiment when only water was given. On the second day varying amounts of horse flesh were fed; on the third day there was a second basal experiment. Three such series of experiments were made. Falta, Grote, and Staehelin argue that since during each week the dog was fasting 3 days and fed 4 days he was more or less in a condition of chronic undernutrition.

The authors compare the fasting value on the first day of the first series of experiments with the fasting value on the third day of the third series of experiments, and note that there is a distinct decrease in the heat production per square meter of body-surface per 24 hours amounting to 8 per cent, *i. e.*, from 918.3 to 844.5 calories. They cite this decrease as evidence of the accommodation of the body to the smaller food intake, and point out that this assumption has heretofore lacked definite proof. In explaining some of the differences found in the results obtained with the various proteins—differences that were, to be sure, very small—they argue that it is possible, inasmuch as there is a reduction in the total heat production in the fasting experiments during a condition of chronic undernutrition, that there may likewise be a lessening in the intensity of the specific dynamic action under conditions of chronic undernutrition.

Two criticisms must be raised against the method of computation used by Falta, Grote, and Staehelin. In the first place they have evidently made an error in computing the body-surface of their dog at the end of the third day of the third period. The initial weight was 23.8

[1] von Noorden, Handbuch der Pathologie des Stoffwechsels, Berlin, 1906, 2 Aufl., 1, p. 486.
[2] Falta, Grote, and Staehelin, Beitr. z. chem. Physiol. u. Path., 1907, 9, p. 333.

kg. and the final weight 22.8 kg., while they report the corresponding body-surfaces as 0.997 and 0.9916 square meters, respectively. Making corrections for this error in the body-surface, the difference in the heat production per square meter of body-surface is slightly under 7 per cent. With such a subtle factor as the influence of undernutrition upon metabolism, it is highly important that only periods of complete muscular repose be compared. Unfortunately the authors had no record of the degree of repose and in their comparisons include the activity for the whole day. The apparent minimum value for the first day of the first experiment is obtained from two periods with an average oxygen consumption of 11.15 grams per hour. That this is probably an approximate minimum value is shown by the fact that the lowest hourly values for carbon-dioxide excretion are likewise found during these periods. The respiratory quotients for the two periods average 0.72. On the third day of the third experiment we have two periods that also give low minimum values, and these again are in a sense controlled by the fact that the lowest carbon-dioxide excretion per hour appears in the same periods. For the oxygen consumption the values are 10.28 and 10.23 grams, with an average of 10.25 grams per hour; the average respiratory quotient is 0.73.

Calculating the calories per hour on the basis of the calorific value of oxygen for these days and using the average respiratory quotients for the minimum periods, we find that on the first day of the first experiment the values are 36.7 calories per hour, 1.54 calories per kilogram per hour, and 37.3 calories per square meter per hour. For the minimum periods on the third day of the third experiment the values are 33.8 calories per hour, 1.48 calories per kilogram per hour, and 35.3 calories per square meter per hour. The nitrogen excretion in the two days was for the first day 0.216 gram per hour during the period of minimum metabolism, and on the last day 0.20 gram. As these are essentially constant values, we may disregard them in our computation of the total metabolism.

From these figures it is seen that on the two days the metabolism, both per unit of body-weight and per unit of body-surface, was essentially constant, *i. e.*, a difference of but 4 to 5 per cent. Thus the entire argument of Falta, Gróte, and Staehelin falls to the ground when based on these experiments, as the results can not be used for positive proof of the assumption that with long-continued undernutrition there is an adjustment of the body to the lower food intake.

*Staehelin, 1909.*—In an interesting address dealing specifically with the problem of the lowering of metabolism, Staehelin[1] cites many of the cases in literature in which normal individuals showed a lowered metabolism and definitely emphasizes the fact that there may be an adjustment of the metabolism to the nourishment.

[1] Staehelin, Deutsch. med. Wochenschr., 1909, **35**, p. 609.

*Hunt, 1910.* The effect of a restricted diet upon the resistance of animals to certain poisons was studied by Hunt[1] in an extensive series of experiments on mice and guinea-pigs. The author assumes that acetonitrile exerts its toxic effects only, or largely, after undergoing changes due to the processes of metabolism, the intensity of the processes of oxidation determining the intensity of the toxic effect. The diet given the experimental animals, while qualitatively the same, was less than that of the animals on the unrestricted diet. The dose of acetonitrile dissolved in water was injected subcutaneously; the amount used was proportional to the body-weight. Only those experiments in which the dose was nearly fatal are cited. It was ascertained as typical of these experiments, that with equal doses of acetonitrile the animal on an unrestricted diet died, while that on the restricted diet recovered. This was interpreted as showing a diminution in the intensity of the processes of metabolism with restricted diet.

*Grafe, 1910.*—In his first publication on metabolism during katatonia, Grafe[2] points out that in spite of what he considers sufficient food, namely, 1,400 calories per day, the body-weight remained constant at 47.5 kg. as compared with an initial weight of approximately 55 kg. He concludes that the body does not exhibit a tendency to increase in weight, and considers this as possibly a peculiarity of katatonia. We have here one of the earliest suggestions in Grafe's writings of the conception of an adjustment of metabolism to food intake, viz., that with increased food intake there is increased energy expenditure.

*Grafe, 1911.*—In a special search for pathological conditions in which a retardation of basal metabolism would be noted, Grafe,[3] in a carefully planned series of experiments, studied the metabolism of patients in psychiatric coma. Obtaining his subjects from the Psychiatric Institute in Heidelberg, he placed them in the Jaquet respiration chamber in the Clinic for experiments lasting from 3 to 12 hours or more. If we consider only those experiments in which the subjects remained very quiet, we find in certain cases of mental disturbance accompanied by stupor that the basal metabolism, either per kilogram of body-weight or per square meter of body-surface (using the Meeh formula), is extraordinarily low. In one case it was 39 per cent below the value selected by Grafe as a normal, namely, 800 calories per square meter per 24 hours.

Grafe finds it difficult to explain this depression in metabolism as being caused by chronic undernutrition. Grafe's patients, although admittedly somewhat undernourished when compared with the average of normal people of the same age, were far from being ema-

[1] Hunt, Public Health and Marine-Hospital Service of the U. S., Hygienic Laboratory Bull. No. 69, 1910.

[2] Grafe, Zeitschr. f. physiol. Chem., 1910, **65**, p. 45.

[3] Grafe, Deutsch. Arch. f. klin. Med., 1911, **102**, p. 15.

ciated. It so happens that the most pronounced depression in metabolism occurred with a woman with a height of 162 cm. and a weight of 71 kg., who was in an unusually good state of nutrition. Recognizing the difficulties of interpreting this phenomenon, Grafe cautiously states that the experiments simply establish the fact that with mental disease there is a true depression in the metabolism. His experiments on subsequent feeding are somewhat less numerous and indicate that while the maximum effect following food may not appear so soon as with normal people, the total increase in oxidation as the result of food ingestion is essentially normal.

It is quite clear, therefore, from this study of Grafe's, that the basal metabolism during conditions of mental disturbance accompanied by stupor may be very considerably lowered. The lowered values are so great that they can not be ascribed to errors in the selection of a normal value or to a possible error in the body-surface values as compared with the more recent body-surface standards of Du Bois. As an indication of the possibility of alteration in basal metabolism the investigation has a profound interest. Since the majority of Grafe's patients were not unduly emaciated, it is quite likely that we deal here with a specific result of the mental condition accompanied by stupor and not to a distinctly undernourished condition of the body with lessened cell-mass.

*Grafe and Graham, 1911.*—The lengthy observation of Grafe and Graham[1] on excess feeding of a 20-kilogram dog has provoked an unusual amount of discussion among physiologists, in spite of the fact that relatively little adverse criticism has been printed. Although primarily considering the question of overfeeding, the experiments have such a bearing on the possible adjustment of basal metabolism to food intake and have received so much attention from physiologists that we feel justified in discussing them here. Personal acquaintance with Dr. Grafe has led to a thorough investigation of this remarkable research, and it is a source of much regret that the present war conditions do not make it possible, before publication, to communicate with Dr. Grafe regarding our critical examination of his study. Although we are forced to dissent from the main conclusions, we are fully aware of the important place that the research has taken in physiological circles and the stimulus it has been to thought and to research.

The dog was first starved for 21 days. It was then given presumably excess food (280 per cent of the basal requirement) until the normal weight was regained (a period of 7 days). This was followed by 29 days of gross excess feeding (300 per cent of the basal needs), and three subsequent periods of 11, 19, and 10 days, respectively, with a smaller amount of food, but still presumably above the normal requirement (200, 130, and *ca.* 100 per cent). During the last three periods the dog remained with an essentially constant body-weight. Grafe argues that

[1] Grafe and Graham, Zeitschr. f. physiol. Chem., 1911, 73, p. 1.

this indicates an adjustment of the body to the excess nourishment. While the main argument is based upon the fact that the body-weight did not change, Grafe presents in addition a number of respiration experiments made during the period of supposed excess feeding, which he compares to a basal value and thus satisfies himself that during the period of excessive feeding there was a very greatly increased *nüchtern* metabolism.

At first sight the experiment seems to be carried out with unusual care and accuracy; furthermore, Grafe gives a very good exposition of the main points under discussion. Unfortunately we find it necessary to differ with him on several fundamental points regarding his main conclusion that the animal was greatly overfed. During the period of 21 days of starvation the animal lost 5.15 kg. in body-weight and approximately 4 grams daily of nitrogen. During the second period, when the body-weight was being regained, Grafe's figures show that the animal received 2,243.9 net calories per day, and the nitrogen storage almost exactly compensated the nitrogen loss during the hunger period. The measurements of the metabolism during the hunger period, however, show that the total caloric loss during the 21 days was 17,403.5 calories.[1] Assuming that the caloric loss was the same, whether or not the animal was inside the respiration chamber, the daily loss would be not far from 829 calories.

During the second period of 7 days, when presumably excess food was given, it is reasonable to assume that the caloric output could not have been much less than 1,000 calories per day. Unfortunately no metabolism experiments after the ingestion of food were made during this period, but in the later experiments reported by Grafe, in which 2,600 or more calories were given per day, the caloric output was 1,200 calories or over; 1,000 calories is therefore a minimum rather than a maximum estimate. Accordingly, during these 7 days at least 7,000 calories would be required. Since the dog was given approximately 16,000 total net calories the amount available for replenishment of the lost tissue and fat in the body was about 9,000 calories, or about one-half that actually lost during the 21 days. Hence it is clear that it is illogical to reason that the animal body was in its original condition at the end of the 7-day period of feeding.

In discussing the metabolism in the 29-day period of greatest excess feeding, Grafe has compared it with the minimum metabolism of the

[1] Computed from table II on p. 18 of Grafe and Graham's paper (*loc. cit.*) as follows:

| No. of days. | Calories per day. | Total. | No. of days. | Calories per day. | Total. |
|---|---|---|---|---|---|
| 2 | 1055.7 | 2111.4 | 2 | 840.1 | 1680.2 |
| 1 | 935.0 | 935.0 | 3 | 762.2 | 2286.6 |
| 3 | 1008.0 | 3024.0 | 3 | 746.2 | 2238.6 |
| 3 | 793.5 | 2380.5 | 4 | 686.8 | 2747.2 |

dog on the last days of fasting, and has computed a value which shows he considers that if the animal weighed 20 kg., it would have a minimum caloric production of 822.8 calories. We believe that Grafe (like Benedict and Carpenter[1] of this Laboratory) has fallen into the error of using fasting values as distinguished from post-absorptive values for his basis of comparison. Benedict and Carpenter have discussed in considerable detail the error in using true fasting days for this purpose, since unquestionably the fast has, *per se*, a specific influence upon metabolism.[2] On this ground the basal value employed by Grafe is altogether too low; according to our computation, the total heat production of the dog would much more closely represent 1,200 calories per day during the period of heavy feeding. Since during this time Grafe states that 2,580 net calories per day were available, the excess would correspond to about 40,000 calories, *i. e.*, $2{,}580-1{,}200 \times 29=40{,}020$.

In the period of 11 days, when feeding with 1,660 calories per day, the maintenance requirement would, in all probability, be not less than 1,112 calories, as found by Grafe. Since this is a *nüchtern* value, during the feeding period it would unquestionably be somewhat higher, leaving the net surplus smaller. Disregarding this point, the net surplus is 548 calories, or a total for 11 days of 6,028 calories. In the next period of 19 days, the food was hardly above maintenance. Using the actual values obtained on those days when respiration experiments were made and the animal was without food in the stomach, the basal value can be assumed to be 1,030 calories. Since the daily energy intake during this period was 1,120 net calories, the surplus energy above maintenance would be only 90 calories daily, with a total excess for the 19 days of 1,710 calories. At the end of this period, therefore, we have a deficiency of 17,404 calories in the first 21 days to be made up, and available for this replenishment 56,758 calories. On this basis one can assume that 39,354 calories were stored in the body. On the basis of 9.5 calories per gram of fat this would correspond to approximately 4,143 grams or 4 kg. of fat.

We believe, however, that Grafe has made a fundamental error in assuming that the heat output of his dog outside the respiration chamber was the same as in the respiration chamber, since his own reports show that the respiration experiments were made at 22° C., while a very large part of the time the dog was in the cellar with a temperature of 15° C., and probably during the night with even a lower temperature. While exact quantitative data regarding the influence upon metabolism of temperature is still too scanty for most accurate computations, it has been the custom of physiologists for many years to use

[1] Benedict and Carpenter, Carnegie Inst. Wash. Pub. No. 261, 1918, p. 72.

[2] Grafe had good precedent for using the fasting value for a base line as in similar comparisons. Johansson, Landergren, Sondén, and Tigerstedt (Skand. Arch. f. Physiol., 1897, 7, p. 29) had previously used values obtained with a man during a fast of 5 days.

the figure obtained by Rubner, which implies an increase in metabolism of approximately 3 per cent per degree centigrade.[1] We thus have a probable increase in metabolism of this animal on the days outside the respiration chamber of not far from 21 per cent or, roughly speaking, one-fifth. With a basal daily requirement of 1,200 calories, this would correspond to 240 calories per day. The four periods when excess food was given numbered 66 days, of which 12 were in the chamber. With an increase in the metabolism of 240 calories per day, there would be a total increase in the metabolism of $240 \times 54 = 12,960$ calories, or one-third of the excess computed by the above method. The excess calories, which amounted to $39,334 - 12,960 = 26,374$, if stored as fat, would correspond to about 3 kg. of fat or 15 per cent of the body-weight of the dog. It should be stated, however, that in a recent investigation by Zuntz[2] a series of experiments carried out with a dog at a temperature of 30° to 32° C. showed 44.4 calories per kilogram per 24 hours and another series at 15° to 16° C. showed 50.2 calories. This difference corresponds more nearly to 1 per cent per degree than to Rubner's figure of 3 per cent used in the above calculations.[3]

Since in our judgment the figures used in our recalculations for the basal metabolism and the estimates of probable energy requirements during repose are minimum rather than maximum, we believe that the experiment of Grafe does not positively prove the main point of his discussion, namely, that the dog, when given excess food, produced a sufficiently excess metabolism to counterbalance it.

A striking factor of Grafe's experiment must not be lost sight of in that throughout the entire period of realimentation there was a very great storage of nitrogen in the body. This storage, unaccompanied by a marked increase in metabolism, is, we believe, fully in conformity with the experience found by A. Müller[4] with man, in which 210 grams of nitrogen were stored without appreciable increase in the heat production per kilogram of body-weight. Although personal conversation with Dr. Grafe gives no clue as to the probability of an increased activity on the part of the dog when outside the chamber, it would appear as if the estimates for the energy requirement on the days when the animal was not in the chamber are too low. If this is the case and if correction is made for the erroneous basal value obtained after a period of prolonged inanition, we believe that the figures would not positively prove Grafe's main contention. The addition of a large amount of protein and certainly of some fat can hardly be accounted

[1] Rubner, Die Gesetze des Energieverbrauchs bei der Ernährung, Leipsic, 1902. Hári (Biochem. Zeitschr., 1914, 66, p. 2) has pointed out that in many of Rubner's experiments the percentage difference per degree is 3 to 5 per cent.

[2] Zuntz, Biochem. Zeitschr., 1913, 55, p. 341.

[3] This difference is at least in part explained by the fact that 32° C. is considerably above the so-called critical temperature for most dogs.

[4] A. Müller, Zentralbl. f. d. ges. Physiol. u. Pathol. d. Stoffw., 1911, N. F., 6, p. 617. See also p. 29 of this monograph.

*Morgulis, 1914.*—Morgulis,[1] carrying out the theories of Zuntz with whom he had worked in Berlin, reports results of an experiment on a dog which was given about one-third of the maintenance requirement in the diet. Prior to the reduction in the diet, the energy requirement was computed from the respiratory exchange to be 39.3 calories per kilogram per 24 hours. As a matter of fact, after the dog had lost 42.35 per cent of his original weight, the energy requirement was 43.6 calories, or 11 per cent more. Wholly inexplicable increases and decreases in metabolism were reported with the resumption of excess feeding.

*Hári, 1914.*—In a carefully planned series of experiments designed to eliminate the question of too low a temperature, Hári,[2] employing all of the usual Budapest accuracy of technique, studied the influence of chronic undernutrition on the metabolism, measuring the heat directly by means of the Rubner calorimeter. Although the experiments were somewhat complicated by the fact that, in the first place, the basal value was obtained in several days of complete fast, that milk was administered at times cold and at times warm, and that the actual amount of energy ingested averaged in all the series about 70 per cent of the maintenance need, Hári has drawn some important conclusions. Of special significance to us in this discussion, however, is the clear relationship he notes between metabolism and loss in nitrogen. The irregularity of his results he explains in part on the ground of individuality. The feeding experiments are usually of such short duration that it is difficult to distinguish between true starvation and the period of chronic undernutrition which in no case continued more than 9 days. Using the fasting days as basal values, Hári notes that when insufficient food is given, there is either a slight increase or a very slight tendency to a decrease in metabolism.

*Loewy and Zuntz, 1916.*—When the research reported by us in this monograph was more than half completed, we were fortunately able to secure a copy of the interesting article by Loewy and Zuntz[3] on the influence of war diet upon metabolism. This gives the results of experiments made in the spring of 1916 in which the investigators themselves were the subjects. Inasmuch as both Zuntz and Loewy had had their basal metabolism measured intermittently for a number of years previous, their probable basal values are significant and afford an excellent basis for comparison with the metabolism determined after two years of war diet.

The experiments were made with the Zuntz-Geppert apparatus and represent (in the case of Zuntz) 5 periods on 3 different days in May 1916. In the case of Loewy they represent 4 periods on 2 days, also in May 1916. Although Zuntz had lost considerable body-weight, never-

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[1] Morgulis, Biochem. Bulletin, 1914, 3, p. 264.
[2] Hári, Biochem. Zeitschr., 1914, 66, p. 20.
[3] Loewy and Zuntz, Berl. klin. Wochenschr., 1916, 53, p. 825.

theless the oxygen consumption and carbon-dioxide production were much lower per kilogram of body-weight than they were under pre-war conditions. The nitrogen excretion per day for Zuntz was relatively small, averaging not far from 6.50 grams. He computes that he was consuming approximately 51 to 52 grams of protein per day. Calculating the calories per square meter on the basis of the Meeh formula, he finds a reduction in heat production per square meter of body-surface corresponding to 7.3 per cent.

With Loewy the loss in body-weight was not so great as with Zuntz. The oxygen consumption per kilogram of body-weight and per square meter of body-surface was considerably reduced, being 12.2 per cent lower per kilogram of body-weight than formerly. Unlike Zuntz, Loewy lived upon a reasonably liberal nitrogen intake, since the nitrogen in the urine averaged 13.95 grams per day. Taking into consideration the nitrogen in the feces, it is computed that the nitrogen content of the food was the equivalent of 97.6 grams protein, or nearly twice that of Zuntz.

As an explanation of this lowering of metabolism, the authors suggest two possibilities: one, that there was a greatly reduced protein intake; the other, that with the loss of body-weight there was an even greater percentage loss of active cell substance. They conclude that the first of these suppositions is disproved by the results obtained with Loewy, who partook of a fairly liberal nitrogen diet. They finally conclude that the main cause of the reduction is the loss of active cell substance and, further, that even if there is a fairly liberal protein intake in the diet, insufficient calories will cause a great loss of active body substance.

Observations of the pulse-rate with Zuntz indicate a slight falling off in the 1916 series of experiments. During this series hemoglobin determinations were made and showed that the blood of both men indicated 110 per cent of hemoglobin on the Plesch hemoglobinometer.

It is thus clear that these two German scientists have definitely shown in their own cases measurably lowered metabolism as a result of the loss in weight incidental to the restricted diet of war times. In our examination of the earlier literature nowhere do we find such clear-cut statements with experimental evidence of the possibility of lowering the basal metabolism of man as are seen in these experiments of Loewy and Zuntz. The conflicting evidence noted throughout the literature for animals and for pathological cases with man is entirely absent in these two series of experiments.

*Jansen, 1917.*—The details of a second war-diet study, which was made by Jansen[1] and confirmed the findings of Loewy and Zuntz, came to our attention only when the report of our research had reached the first galley proof and hence too late for extended analysis. With 13 subjects Jansen studied the influence of a low-calorie diet upon the

[1] Jansen, Deutsch. Arch. f. klin. Med., 1917, **124**, p. 1.

nitrogen balance. All of the subjects, with the exception of two women in the group, had lost not far from 8 to 10 per cent in body-weight since the beginning of the war. The diet, which corresponded to the Munich ration in March 1917, had an energy value of about 1,600 (gross) calories per day, with a nitrogen content of approximately 9.7 grams (or 60.5 grams of protein) and contained 210 grams of carbohydrates. On this diet there was an average loss of nitrogen for the whole group of about 2 grams per day and an average loss in body-weight of 0.28 kilogram per day.

Respiration experiments were also made by the Zuntz-Geppert method with two subjects 23 and 26 years old, and of the same height and weight, *i. e.*, 174 centimeters and 56.1 kilograms. The basal heat production per 24 hours found in these experiments was 1,338 calories and 1,456 calories, respectively, while on the basis of per kilogram of body-weight it was 23.8 and 25.0 calories, respectively. Jansen points out that these values are low as compared with Magnus-Levy's values for normal subjects of like weight[1] and refers to the explanation of Loewy and Zuntz that this lowering in metabolism is due to the loss in active cell substance.

The basal metabolism of these subjects after a 3-day walking trip was again measured 12 hours after the last meal and after work and was found to be very greatly increased. The post-absorptive respiratory quotients for both subjects varied considerably, *i. e.*, from 1.29 to 0.78 and from 1.10 to 0.86, respectively, whereas in the previous series of experiments the quotient had averaged about 0.87. The oxygen consumption likewise varied considerably with one subject, and the lung ventilation was greatly increased. Jansen concludes that this amount of exercise, which would not be considered at all strenuous with a well-nourished man, produced with these subjects on restricted diet an extraordinary exhaustion and affected the respiratory exchange even after 12 hours of repose, this being shown by abnormally high values for oxygen consumption and the respiratory quotient. Unfortunately the respiratory data, judged in the light of our own observations, seem to be of uncertain value. Such astonishing alterations in the respiratory quotient and, indeed, in the basal oxygen consumption, are outside of our experience. It is to be hoped that the data will be supplemented by publications from other European laboratories where metabolism studies on the influence of a reduced diet have doubtless been made.

## SUMMARY OF PREVIOUS LITERATURE.

In studying the results of previous investigations on undernutrition, it is of the greatest importance to note that there is a marked difference

[1] Calculation by the Harris-Benedict multiple prediction formula (Harris and Benedict, Carnegie Inst. Wash. Pub. No. 279, 1919) gives 1,553 and 1,533 calories per 24 hours, respectively, *i. e.*, 16 and 5.5 per cent above the found values.

reduction, while Zuntz[1] and Caspari[2] both specifically state that owing to the restlessness of the subject they are certain that the basal value has not been found. It thus follows that if the basal value on this man had been found, depressed metabolism would surely have been indicated.

If it were not for the specially clear evidence obtained from the recent experiments of Loewy and Zuntz, little of positive assurance could be derived from the literature. These experiments, taken in connection with the evidence presented by many of the earlier workers, indicate that with undernutrition there is a loss in weight and a tendency to a reduced metabolism. With a loss in body-weight, one would expect to find a lowering of the total metabolism, but with Loewy and Zuntz, and, to a certain extent, with Jansen's subjects, the metabolism per kilogram of body-weight was likewise distinctly lower during the reduced diet, thus showing that the basal metabolism was specifically lowered. This, they believe, was due to the loss of organic tissue. We thus have here a clear indication of a lower plane of nutrition. Such a change in nutritional level is also indicated by Rubner in his statement in enunciating his law of surface area that animals compared should be in the same state of nutrition.

On the basis of this evidence, one would expect to find, when examining the basal metabolism of normal men and women, that individuals of very low weight would have a low metabolism, both per kilogram of body-weight and per square meter of body-surface. In fact, data show clearly that thin people have a higher metabolism per kilogram of body-weight and as high a metabolism per square meter of body-surface as have fat people of the same age,[3] for while Means[4] contends that the heat per square meter of body-surface is the same with fat people as with the Du Bois normals, the obese usually give very low values per kilogram of body-weight. Furthermore, athletes (from whom presumably a large amount of body fat has been removed by training) show a higher metabolism than normal, although this is in large part due to the stimulus of cellular activity incidental to excessive muscular exercise. Considering individuals in general, therefore, the composition of the body appears to be of appreciable significance, and one may not state that 1 kg. of fat has the same heat-producing power as 1 kg. of active protoplasmic tissue. Consequently one would reason that when fat is lost, there would be a specific increase in the heat production per kilogram of body-weight. Quite the contrary was observed by Loewy and Zuntz.

On the other hand, aside from fat people, diabetics subsequent to the fasting treatment, and a man fasting 31 days, we have found no class of

[1] Zuntz, Biochem. Zeitschr., 1913, **55**, p. 342.
[2] Caspari, Arch. f. d. ges. Physiol., 1905, **109**, p. 564.
[3] Benedict, Journ. Biol. Chem., 1915, **20**, p. 282.
[4] Means, Journ. Med. Research, 1915, **32**, p. 121.

weight and are thin and well trained down. In view of the experience of the German nation, it seemed feasible to alter experimentally the food intake and in consequence probably alter the nutritional level.

It was first thought that such a study could be made with a group of men who had already considerably reduced their body-weight by dietetic alterations. Athletes who had suddenly lost much flesh in preparation for an athletic contest were first considered, but it was decided that athletes are trained not only to lose flesh but at the same time to retain their excessive strength. Dr. George P. Denny, who was at this period a collaborator at the Nutrition Laboratory, then offered to secure the services of a number of coxswains from the boat crews of Harvard University. Such men should be well suited for observations of this kind, as it is necessary for them to train down to a low body-weight, but at the same time no special strength is required in their duties. Simultaneously with the inception of this project, war was declared between the United States and Germany and the athletic plans of Harvard University were entirely revolutionized. It was therefore necessary to give up the idea of a research with coxswains and seek elsewhere for the ideal subjects for the contemplated study. It was finally decided to secure a number of normal individuals and study the metabolism during a long period of low food intake.

## GENERAL PLAN OF RESEARCH.

To have such a study of direct practical value, these men must be living normal lives and carrying out their regular activities in the community. Furthermore, they should be of normal weight, rather than obese, to avoid introducing the pathological factor of obesity. In Germany there was at first a somewhat acute period of loss in weight, caused by the sudden stringency in food materials and the inability of the people as a whole to adjust themselves rapidly to the lowered food intake. There was then a period in which the redistribution of food made it possible to hold the body-weight at the lower level. Our study with the group of normal men was therefore made along two definite lines, *i. e.*, to determine the physiological effect of a pronounced reduction in diet under the following conditions:

(*a*) During the period of loss in weight when the energy of the diet would be supplemented to a considerable extent by drafts upon body material.

(*b*) During the period of subsequent feeding with a diet selected to maintain the body in equilibrium at the lower body-weight.

During such weight reduction previous experience with fasting men had shown that there would be in all probability a loss in nitrogen, certainly a loss in body-fat, and probably a somewhat lower heat output. Hence it was recognized that the following special records should be made:

First, the total caloric intake of each individual should be obtained, both during the period of loss in weight and especially during the period of maintenance at the lower body-weight.

Second, the total changes in body nitrogen should be determined by establishing a continuous nitrogen balance until equilibrium was subsequently found at the lower weight level.

Third, there should be records of the body-weight, with observation of the fluctuations and the causes therefor, recognizing the fact that sharp fluctuations in body-weight may in large part be attributed to changes in the water content of the body.

Fourth, a record should be made of the general physical well being, this to include measurements of strength.

Fifth, since it was highly important that possible impairment of the intellectual and physical ability should not be overlooked, continuous and careful records of neuro-muscular processes should be obtained.

In connection with such a research, the following questions naturally suggest themselves:

(1) Is it possible to alter the basal metabolism by a reduced ration?

(2) Can the body be held in nitrogen and carbon equilibrium at the lower level?

(3) If such a lowering in basal metabolism is obtained by a reduction in diet, will the lowering be proportional to the reduction in weight, that is, if there is a loss of 10 per cent in body-weight, will the basal metabolism be 10 per cent less than the normal metabolism or will the basal metabolism per kilogram of body-weight be unlike at the two nutritional levels?

(4) Since the body material lost would presumably be in greater part fat, and thus supposedly inactive in metabolism, will the basal metabolism increase with the loss in weight, as would be expected, or will it decrease?

(5) Will superimposed muscular work be done at a higher or lower cost of energy at an altered level of basal metabolism?

(6) Will the stimulating effect of foodstuffs, primarily that of protein, be the same with reduced body-weight as with the normal body-weight?

As the result of our research, we were able to make material contributions on the first five problems, and suggestions on the sixth may also be found in our data.

The larger portion of the preliminary plans for this research were made in conference with our colleague, Dr. Thorne M. Carpenter, who had expected to be actively associated with this work. An unfortunate typhoid fever infection in the early fall made it necessary for him to withdraw completely from the investigation, although in the last few weeks he kindly cooperated in some of the temperature and pulse measurements. His absence from the Laboratory was keenly felt by all, since we had greatly counted on his counsel and cooperation. Fortunately, the entire manuscript has had his critical reading.

## REDUCTION OF BODY-WEIGHT OF SUBJECTS.

In our research on the effect on the metabolism of reducing the body-weight by alterations in diet, several plans for reducing the weight of the subjects suggested themselves. The total weight reduction was tentatively set at 10 per cent in the belief that a 10 per cent loss would be of sufficient magnitude to show positively any changes in the metabolism, while a percentage less than this might not be measurable with

many of the factors. A greater reduction in weight would prolong the experiment and require greater dietetic control; the amount of discomfort might be taken as roughly proportional to the degree of loss.

Previous experience with fasting men has shown that it is perfectly safe and not productive of great discomfort to fast completely for several days. While the loss of 10 per cent could be secured by complete abstinence from food (judging from our experience with the man fasting for 31 days this loss could be obtained in a period of complete fasting of 14 days), it was recognized that it was impractical to ask a group of men to sacrifice their entire time to a test of this kind and to undergo a complete deprivation of food for 14 days. Consequently it was considered best to produce the loss in weight by the administration of a diet so reduced that there would be each day material drafts upon body fat. It was therefore tentatively proposed that the ingesta should be approximately from 50 to 70 per cent of the actual food requirements.

After the reduction in body-weight of 10 per cent had been reached, the basal ration was then to be supplemented in each case with sufficient energy in food materials to hold the body-weight at the lower level and an attempt made to obtain nitrogen equilibrium as soon as possible. Carbon equilibrium or energy equilibrium would be indicated by constant body-weight over a period of weeks; nitrogen equilibrium would be shown in the usual manner by the balance between the nitrogen in the intake of food and the nitrogen in the feces and urine.

From our experience with fasting men and from the experience of this Laboratory in conjunction with Dr. E. P. Joslin in studies of diabetics with their extreme losses, it appeared perfectly safe to attempt an observation of this kind, since the reduction in body-weight was to be but 10 per cent or slightly more.

## SELECTION OF SUBJECTS.

For the study of so important a problem as the influence of undernutrition upon basal metabolism and vital processes in general, it was essential that the subjects of the research should be men rather than animals, especially as the nation is not so much interested in the better utilization of feeding stuffs for animals as it is in the utilization of food for man. This naturally increased our responsibility and financial obligations, as only those having actual experience with this type of work can realize. Investigators who work entirely with small animals and domestic fowl can have little conception of the perplexities which arise in working with a considerable number of adults.

Observations on one man may be considered in general as typical of observations on men as a whole until striking abnormalities or variations are shown. Thus the ingestion of 100 grams of sugar produces a

(2) *They should be responsible, cooperating, and truthful* men, for in a study continuing over a period of 3 or 4 months and involving the strictest fidelity to general plan, especially in regard to dietetic habits, the whole success of the venture would, in the last analysis, depend upon absolute veracity.

(3) *They should be volunteers*, for men assigned to such a research would not enter into it whole-heartedly. For this reason soldiers detailed for such duty, even those belonging to a medical ward, would not be likely to give the cooperation we desired. For many physiological studies prisoners or other institutional inmates would prove ideal subjects, but would not be suitable in this case, if the service were compulsory; if prisoners volunteered in response to such rewards as an abatement of sentence, their use would then be justifiable.

(4) *The subjects should not consider themselves obligated to volunteer*, or if they felt they were forced into a test of this character, they could not cooperate to the extent that the investigations demanded.

(5) *They should be willing to undergo a certain amount of privation and discomfort*, for there would be more or less restriction as to the usual habits, dietetic customs, social environment, etc.

(6) *They should preferably be living under community conditions*, such as dormitory life, with regularity of daily routine. This would assist materially in the dietetic control and the collection of urine and feces required in the daily routine.

(7) *They should be willing to serve as subjects for several months*, since the time, labor, and money investment for each man would increase as the research progressed and his loss as a subject be more serious if his individual observations were incomplete.

(8) *They should have a unity of interest.*—In military phraseology, the "squad" system was emphasized. The personal influence was made a feature of the entire research, with the idea that each man would not only perform his own part in the observations successfully, but that his moral support would render material assistance to each of his associates.

(9) *The subjects should be as varied in type as practicable.*—While not all types of physical and intellectual activity could be studied in the research, yet since the average man is more or less intellectual, and possesses a fair degree of physical development, it was desirable to select as nearly as possible a group equally divided between those who paid special attention to physical development and those whose activities were more exclusively intellectual.

## FINAL SELECTION OF MEN.

The finding of men who should have all of these qualifications required careful consideration of various possibilities. After a period of several months, it was finally decided that a group of students could best be chosen from the International Young Men's Christian Asso-

ciation College in Springfield, Massachusetts. The desirability of such a selection is shown by the following facts:

In the first place, the students in this college are all professing Christians, their admission to the institution being dependent upon high moral character combined with intellectual and physical fitness. The men would thus be clean-lived and with good histories as to excesses of all kinds. The question of tobacco and alcohol would also be eliminated and a good physical condition be assured. The ethical standards are high and the honor system obtains in every phase of the college life.

Still another reason for selecting students from this college is the unusual interest in physiological problems throughout the college body. This is due in large part to the active interest in and contributions to physiology made by Professors J. H. McCurdy and Elmer Berry, whose personal cooperation and assistance in many details at Springfield were admittedly great assets in beginning an investigation of this kind. The contributions of both these gentlemen to physical education are well known.

It was a source of great regret to us that, owing to the pressing demands of the Young Men's Christian Association under the present war conditions in France, Professor McCurdy left America for that country before our investigation actually began. This was not only a great loss to us in carrying out the investigation, but necessitated a considerable addition to the already burdensome administrative work of Professor Berry, which prevented him from giving so large an amount of time to the research as he otherwise would have done.

Notwithstanding the fact that the distance from Boston (100 miles) required a large expenditure for transportation of apparatus, samples, and subjects, the wisdom of selecting men from this institution was repeatedly proved and never questioned during the research. At no point were we disappointed in the group of men selected, in their fidelity and interest, or in the general spirit of cooperation and friendliness exhibited by the teaching staff of the college, especially by President Laurence L. Doggett. Our obligations to Professor Elmer Berry are beyond adequate expression. The keen cooperation of Professor A. G. Johnson in a number of the measurements of physical achievement was likewise highly valued. A factor of most vital importance was the assistance of Chef Arthur M. Hall, of the Students' Dining Association, whose faithfulness and good nature under most trying and perplexing circumstances made possible a dietary control that we believe is rare in the annals of physiological experimenting.

Although the decision to undertake this investigation was made in the spring of 1917, it was of course impossible to begin the observations until the opening of the academic year in the fall. Throughout the summer much time was given to a further elaboration of the program of the research, to the construction and testing of apparatus, and to

committee of the faculty. He furthermore understands that at the conclusion of the research he will be requested to make affidavit, on his honor as a gentleman, to the fidelity with which he has lived up to the regulations of the research, the careful reading of which is attested by signature to this instrument."

Although there were certain physiological controls on the strict adherence to diet, in the last analysis it would be necessary to rely upon the honor of the men. With the magnificent college spirit and the high ethical standards obtaining in this college, one might at the outset assume without further evidence that the greatest fidelity and honesty of purpose would be assured. According to the honor system which was in active operation in the college, a subject would be in honor bound not to violate the conditions of the experiment and likewise in honor bound to report any known violation by fellow members of the squad.

The importance of absolute fidelity in the dietetic control can hardly be overestimated. For instance, if the record of the protein intake were not complete, due to the fact that the subject took excess food away from the training table, the nitrogen balance, which has assumed much prominence in this research, would be invalidated. Similarly if there were an incomplete collection of urine, the computation of the nitrogen balance would not be accurate. If, however, there were marked fluctuations in the nitrogen excretion in the urine which could not be accounted for by similar fluctuations in the nitrogen of the diet, it would be reasonable to suspect an infringement of the rules. Of course it would have been possible for a subject to take excess protein food and designedly give incomplete returns for the total urine excreted or report that the urine was lost, but we are certain that no such instance occurred.

It is, however, with the energy balance that the personal veracity of each man is the more important, for an energy balance computed from the measurement of the intake of food and the output in the urine and feces can have no value without the assurance that the measurement of the energy in the diet agrees with the actual daily intake. Without this assurance, the whole study from the standpoint of energy, which is of fundamental importance in this research, would be useless. Thus we see that the honor, personal integrity, and fidelity of our subjects are the greatest assets that we could have in the selection of a group of men for this type of experimentation.

We should here assert our belief in the honor and fidelity of these men. Throughout the entire four months of the investigation there was but one suspected violation of the rules. This was early in the series when there was a marked increase in the nitrogen excretion on one day with one subject, which was coincident with certain social functions. This led us to consider the possibility that the man had violated his agreement, although no report was made of it. Instead of making the direct charge, we argued that if he had violated the agree-

ment once and it was unnoticed, he would certainly repeat the offense. It is a great pleasure to record that there was no other instance in which there was even a suspicion of an infringement. We now believe that the apparent violation of the rules was due to a gross error in reading the volume of urine. As stated earlier, these men were all professing Christians, but the men either refused to take the sacrament at church or else took it and reported the fact in accordance with the agreement in the affidavit. Our own personal belief is that none of the 26 men wilfully infringed the rules at any time during the research. The number of instances in which the students reported minor violations of the rules were so rare as to lead us to believe that throughout the entire period the 26 men used in the research considered it to be a serious phase in their academic life and lived up to the high standards of the college. We place special emphasis upon this point, as it indicates that the selection of subjects from the college body of the International Y. M. C. A. College at Springfield, with the high ethical standards obtaining, the honor system, the unusual interest in and appreciation of physiological experimentation and the importance of service in the national food crisis, was particularly fortunate.

## PERSONAL HISTORIES.

The brief personal history for the individual subjects which follows includes the full name, date of birth, home address, age at the beginning of the experiment, height, initial nude weight, and the result of the preliminary physical examination by Dr. Walter H. Chapin of Springfield, Massachusetts. Under "personal data" are included various miscellaneous incidents during the progress of the experiment, more especially those relating to the physical condition of the subject. The physical characteristics of the family of the subject are given under "family history." The course taken in college and the physical activities of the subject are likewise included in the data. The personal histories for Squad A are naturally more detailed than those for Squad B. *For subsequent reference in a large number of tables, abbreviations of the names of the subjects seemed essential. Consequently throughout the book, the men are usually designated by the first three letters of the surname in each case.* The personal history of each man is given under this arbitrary designation for ready reference.

### SQUAD A.

#### BRO.

George A. Brown; born Sept. 27, 1891; home Rochester, N. Y.; age 26 years; height 167 cm.; nude weight 61.75 kilos. *Medical examination:* Oct. 2, 1917, negative. *Family history:* Only child; father and mother thin; no tuberculosis. *College course:* Physical. *Personal data:* Dislocated toe in playing football; in hospital night of Nov. 1–2, 1917. Under ether 7 to 9 p. m. while toe was set; no ill effects except slight nausea, but no food ejected in vomiting. No supper Nov. 1; breakfast at hospital Nov. 2; returned to

training table for dinner on that day. On crutches about 4 days; foot in cast 11 days; unable to exercise much for about 3 weeks after accident. Looseness of bowels Dec. 10. *Physical activities:* Captain of second soccer team. According to personal estimate Sept. 27, about 25 hours a week spent in physical exercise, such as walking, playing tennis, football, gymnasium work, etc. Oct. 23, seen running up dormitory stairs two steps at a time and whistling; Dec. 4, observed in gymnasium class by one of us and doing as well as average of class. Feb. 1, at 12 noon, "chinned bar" in gymnasium 12 times, equaling previous best record which was two years before. Same date, took part in arm-holding contest, continuing for whole period of 1 hour.

CAN.

Kenneth B. Canfield; born March 6, 1892; home Somerville, Mass.; age 26 years; height 177 cm.; nude weight 79.75 kilos. *Medical examination:* Nov. 21, 1917, negative. *Family history:* Mother somewhat stout; maternal grandfather stout (weighed 200 pounds); subject resembles mother; no tuberculosis. *College course:* Secretarial. *Personal data:* Oct. 24, tired and tooth ached. Oct. 27–28, severe headache when he went into chamber at beginning of experiment. Nov. 4, complained of being cold and of low body temperature. Nov. 16, more or less stiffness, particularly in muscles of thighs. Nov. 27, light case of tonsilitis; throat red, congested, and several patches on tonsils; tonsils somewhat swollen; temperature sub-normal; chilly; well Dec. 5. *Physical activities:* Sept. 27, according to personal estimate, about 12 hours per week spent in physical exercise, such as walking, playing tennis, football, gymnasium work, etc. Nov. 11, took 4-mile walk. Jan. 26, seen running upstairs. Feb. 1, at 12 noon, "chinned bar" in gymnasium 5 times; probably this his best record. Same date, took part in arm-holding contest for 37 minutes of the 1-hour test; third man of Squad A to fall out.

FRE.

Lester F. Fretter; born Nov. 18, 1892; home Cleveland, Ohio; age 25 years; height 167 cm.; nude weight 57.5 kilos. *Medical examination:* Oct. 2, 1917, negative. *Family history:* No record. *College course:* Physical. *Personal data:* Oct. 20 developed pain and soreness in epigastrium; pain relieved on eating. Examined by Dr. Chapin Oct. 22; possibility of gastric ulcer; again examined by Dr. Chapin Oct. 24, who reported the subject was undoubtedly undernourished for the amount of work he was doing in college and advised his being relieved from squad duty; dropped from squad Oct. 25; last day at training table Oct. 24. *Physical activities:* According to personal estimate Sept. 27, spent about 25 hours a week in physical exercise, such as walking, playing tennis, football, gymnasium work, etc. Led gymnasium classes at high school.

KON.

Everett R. Kontner; born Feb. 7, 1898; home Nelsonville, Ohio; age 20 years; height 168 cm.; nude weight 69 kilos. *Medical examination:* Not made. *Family history:* Mother has slight tendency to obesity; no tuberculosis. *College course:* Physical. *Personal data:* Joined Squad A Oct. 30, 1917, as successor to *Fre.* Nov. 16, nasal catarrh with some headache for two days preceding. Nov. 18, in playing football, muscles of left arm strained and injury to nose, possibly nose broken. Nov. 19, reported nose not broken and accident not serious. Nov. 30 entered hospital for removal of part of turbinated bones, tonsils, and adenoids, and for straightening of septum of nasal cavity; discharged from hospital evening of Dec.

1; received treatment until Dec. 17; wore solid rubber tube in left nostril from Dec. 3 to about Jan. 16, to hold septum in position; unable to secure perfect closure with nose clips in portable respiration apparatus experiments until about Dec. 11, when physician allowed him to remove tube during the experiments. Dec. 9, headache. Dec. 12, felt weak. Dec. 13, temperature (oral) 103° F. in morning; excused from portable respiration apparatus experiment and sent back to bed; temperature at $9^h30^m$ a. m., 101.2° F., with severe headache and fever, probably due to infection of frontal sinus as result of nasal trouble; fainted while telephoning to physician. Dec. 14, felt much better, though a little light-headed; no fever; pulse-rate, 50; came to table for dinner. Dec. 16, headache in morning. Dec. 17, well; little looseness of bowels. Dec. 29, after a week's illness with apparent bowel infection, treated by physician, who diagnosed it as intestinal grippe. Jan. 22, more turbinated bone removed from left nostril. *Physical activities:* On football team; excused from game Nov. 2 because his play was weak. Suggestion made Nov. 7 by member of faculty that subject should not be permitted for a time to play with football team in games against other teams; Nov. 16, statement made by subject that he had been doing a considerable amount of physical work; Nov. 18, played football at Suffield, Connecticut. Jan. 15, observed by one of us in gymnasium class as doing as well as average in class. Jan. 23, reported as not attending gymnasium classes owing to too small an amount of food for taking part in the gymnastic work. Feb. 1, 12 noon, "chinned bar" 12 times; had never tried it before. Same date, in afternoon, took part in arm-holding contest for 21 minutes of the 1-hour period; second man of Squad A to fall out.

GAR.

Greyson C. Gardner; born Aug. 16, 1895; home Cottage Grove, Indiana; age 22 years; height 171 cm.; nude weight 71.25 kilos. *Medical examination:* Oct. 2, 1917, negative. *Family history:* Resembles father, who is muscular but not fat; mother has grown stout in recent years; one uncle very stout. Two brothers and one sister, none of them stout. His sister (27 years old) has tuberculosis. No other cases of tuberculosis among relatives. *College course:* Physical. *Personal data:* Nov. 23 to 27, ill with cold, part of time in bed. Nov. 25, reported in morning that he was not feeling well; had not felt well at times for several days; made call in Holyoke, but was feverish, with chills, and obliged to lie down. Came back to Springfield in automobile; could hardly stand and almost fainted in getting out of car. Bowels unaffected; not constipated. Temperature about 9 p. m., 103° F., pulse 66; throat a little sore; feverish, with cold feet, backache, and soreness back of neck; physician called and prescribed for cold. Nov. 26, better; temperature at $11^h30^m$ a. m., 100° F., pulse 56. Nov. 27, $8^h15^m$ a. m., temperature 97.4° F., pulse 44. Dec. 11, diarrhea. Jan. 23, felt weak. *Physical activities:* According to personal estimate Sept. 27, about 27 hours a week spent in physical exercise, such as walking, playing tennis, football, gymnasium work, etc. Nov. 15, played football on class team. Jan. 26, at 1 p. m., was seen to run downstairs. Gymnasium teacher at Springfield high school; six classes alternate days. Feb. 1, at 12 noon, "chinned bar" 22 times; probably equal to his best record. Same date, in afternoon, took part in arm-holding contest for full period of 1 hour.

GUL.

Otto A. Gullickson; born July 18, 1893; home Enderlin, North Dakota; age 24 years; height 166 cm.; nude weight 66.75 kilos. *Medical examination:* Nov. 21, 1917, negative. *Family history:* Mother fleshy (5 feet 6 inches,

weighs 195 pounds); two brothers and one sister thin; father very thin. No tuberculosis. *College course:* Physical. *Personal data:* Nov. 12, bowels affected. Nov. 26, pain in stomach. Dec. 11, diarrhea. Volunteered to give one pint of blood for blood transfusion at Springfield Hospital; Dec. 23, 100 c.c. blood taken; Dec. 29, 50 c.c.; Jan. 6, 90 c.c.; Jan. 17, 50 c.c.; total amount, 290 c.c. Report by physician; "Group III, Moss classification, negative Wassermann reaction." Feb. 5, sensation of fullness in stomach; unbuttoned vest. Feb. 5, vomited at night, expelling his dinner. At Boys' Club, Springfield, each night until 11 o'clock. *Physical activities:* According to personal estimate Sept. 27, about 33 hours a week spent in physical exercise, such as walking, playing tennis, football, gymnasium work, etc. Nov. 15, played football on class team. Jan. 19, when fasting completely, "chinned" 12 or 13 times. Feb. 1 at 12 noon, "chinned bar" 14 times; 1913 record, 24 times. Same date, in afternoon, took part in arm-holding contest, continuing for whole period of 1 hour.

MON.

KIRK G. MONTAGUE; born Aug. 10, 1885; home Portland, Oregon; age 32 years; height 171 cm.; nude weight 68.75 kilos. *Medical examination:* Oct. 2, 1917, negative. *Family history:* Father and mother stout and tall, but not obese. Has three brothers who are fat; subject would resemble them were it not for exercise and work. *College course:* Physical. *Personal data:* Nov. 12, after uncontrolled Sunday had gas in stomach. Nov. 16, not so much vigor as used to have; thinks he is unable to study as well. Nov. 26, not feeling perfectly well. Dec. 14–16, using gargle for throat, which is a little sore; no temperature. Dec. 18, slight cold. *Physical activities:* According to personal estimate Sept. 27, about 35 hours a week spent in physical exercise, such as walking, playing tennis, football, gymnasium work, etc. Nov. 14, played football on class team. Jan. 15, observed in gymnasium class by one of us and did as well as average of class. Feb. 1, at 12 noon, "chinned bar" 13 times; previous record unknown. Same date in afternoon, took part in arm-holding contest for full period of 1 hour.

MOY.

HENRY A. MOYER; born Oct. 27, 1894; home Rochester, New York; age 23 years; height 174 cm.; nude weight 63.50 kilos. *Medical examination:* Oct. 2, 1917, negative. *Family history:* Only child. Mother dead; no knowledge of how much she weighed. Paternal grandfather thin; father normal; subject resembles father. No tuberculosis. *College course:* Secretarial. *Personal data:* Nov. 12, some stomach trouble. Dec. 12, able to get on with little sleep, but feels weak. *Physical activities:* According to personal estimate Sept. 27, about 25 hours a week spent in physical exercise, such as walking, playing tennis, football, gymnasium work, etc. Nov. 13, finished third out of 20 men in 5-mile cross-country run. Nov. 19, was met running towards Woods Hall, and remarked "lots of 'pep' this morning." Feb. 1, 12 noon, "chinned bar" 8 times; record previous summer, 12 times. Same day, in afternoon, took part in arm-holding contest for full period of 1 hour.

PEA.

ALLEN S. PEABODY; born Nov. 6, 1896; home Bradford, Massachusetts; age 21 years; height 169 cm.; weight 69.25 kilos. *Medical examination:* Oct. 2, 1917, negative. *Family history:* No obesity; no tuberculosis. Four brothers and one sister, all normal. *College course:* Physical. *Personal data:* Nov. 3, changed to heavy underwear on account of feeling cold; expected to

sister, considered a consumptive, but appears to have recovered; now 53 years old and comfortable, but cannot live on sea coast. Father refused life insurance by Connecticut Mutual Life Insurance Co. a number of years ago because underweight and suspected of incipient tuberculosis; received a policy from New York Life Insurance Co. and later from another insurance company in Philadelphia. Dr. Goodall found in the tip of one of the lungs of *Spe* a spot that looked as if there had been a process there, but otherwise nothing significant. *College course:* Physical. *Personal data:* Oct. 26, *Spe's* pulse took an unusually long time to return to normal after bicycle riding; he was feverish; Oct. 27, 1917, fever night before and pulse unsettled; believed he had the grippe; face somewhat flushed and bad odor to breath; Oct. 28, 1917, reported himself all right; Nov. 16, toothache; slight infection of gums over wisdom tooth; gum lanced; toothache promptly relieved; Nov. 18 and 19, felt fine; Nov. 26, felt all right; Dec. 10 and 11, felt fine; Dec. 12, felt weak, throat a little sore, temperature at $5^h45^m$ a. m., 99.6° F.; excused from respiration experiment; stayed in bed, headache, appetite poor; Dec. 13, felt better, temperature 100.5° F.; temperature taken later by physician and reported as 102° F. (pulse 120); at 2 p. m. physician suspected typhoid fever; at $6^h30^m$ p. m. temperature 102.5° F., pulse 102; Dec. 14, after consultation of two doctors case pronounced probably typhoid; Dec. 15, went home to Andover; case pronounced typhoid fever by Andover physician; returned to college Apr. 2, 1918. *Physical activities:* According to personal estimate Sept. 27, 1917, about 28 hours a week spent in physical exercise, such as walking, playing tennis, football, gymnasium work, etc. Nov. 14, played football on class team.

TOM.

LESLIE J. TOMPKINS; born July 21, 1892; home Yonkers, New York; age 25 years; height 176 cm.; nude weight 59.50 kilos. *Medical examination:* Oct. 2, 1917, negative. *Family history:* All relatives either normal or thin on both sides of family; only brother thin. Mother died of pulmonary hemorrhage due to tuberculosis. *College course:* Secretarial. *Personal data:* Nov. 16, said he had no ambition and could not take more exercise than he was then taking; thought he needed more sleep. Nov. 25, took cascara. Dec. 3, had had diarrhea, probably as a result of eating greens two or three days before; still had pain and loose bowels. Dec. 6, copious stools. Dec. 12, no bowel movements since the first part of the week, 2 or 3 days before. Dec. 16, bowel trouble due to something eaten; other students eating at Woods Hall were also affected. At 11 a. m., temperature 96.8° F.; pulse 44. Dec. 17, still some diarrhea. During the Christmas holidays hemorrhoids developed, forming a blood clot, necessitating an operation. Operation for blood clot Dec. 24 and for hemorrhoids Dec. 27; ether both times; spent over one week in hospital. Left hospital Jan. 2 and returned to college Jan. 11, feeling somewhat weak and considerable discomfort from operation. Jan. 13, much difficulty in moving bowels; rectum irritated and skin about anus raw. Jan. 15, throat dry, headache, and so ill that he went to bed. Jan. 17, passed some blood at end of bowel movement. Jan. 23, felt weak. Jan. 24, considerable weakness and able to exercise but little. Jan. 25, delegate to Y. M. C. A. convention in Boston. Feb. 5, went to turkey dinner at *Pec's*, ate more than *Vea*. Sick Feb. 6. Managed college store during winter. *Physical activities:* According to personal estimate Sept. 27, about 25 hours spent each week in physical exercise, such as walking, playing tennis, football, gymnasium work, etc. Feb. 1, 12 noon, "chinned bar" 7 times; best record 12 times one year before. Same date, in afternoon, took part in arm-holding contest, continuing 18½ minutes of 1-hour period; first man of Squad A to fall out.

VEA.

RONALD T. VEAL; born Sept. 6, 1895; home Michigan City, Indiana; age 22 years; height 175 cm.; nude weight 65.75 kilos. *Medical examination:* Oct. 2, 1917, negative. *Family history:* Most of mother's family fleshy; father's family thin; subject resembles father. *College course:* Secretarial. *Personal data:* Nov. 7, had cold, sore throat, and felt ill. Dec. 10, felt chilly at supper time, but no sore throat. Dec. 12, was nervous; hardly able to shave. Jan. 31, counted pulse sitting in class at $10^h15^m$ a. m., 32 per minute; later, lying down for about 4 minutes in his room, at $11^h30^m$ a. m., 28 per minute. *Physical activities:* According to a personal estimate on Sept. 27, about 21 hours a week spent in physical exercise, such as walking, playing tennis, football, gymnasium work, etc. Feb. 1, at 12 noon, "chinned bar" 5 times; best record 15 times three years before. Same date, in afternoon, took part in arm-holding contest, continuing to end of 1-hour period.

SQUAD B.

FIS.

EDWARD M. FISHER; born Aug. 10, 1891; home Reading, Pennsylvania; age 26 years; height 177 cm.; nude weight 76.0 kilos. *Family history:* Father 5 feet 10 inches and weighs 230 pounds. Mother normal, has three sisters, all healthy, not stout, also two brothers normal. No tuberculosis. *College course:* Physical. *Personal data:* Operation for hernia; in hospital Dec. 4–19, inclusive.

HAR.

VICTOR H. HARTSHORN; born Mar. 9, 1898; home Washington, D. C.; age 20 years; height 175 cm.; nude weight 63.0 kilos. *Family history:* Mother and father both rheumatic. *College course:* Physical. *Personal data:* No record.

HOW.

KARL Z. HOWLAND; born Mar. 12, 1899; home Phillips, Maine; age 19 years; height 179 cm.; nude weight 70.0 kilos. *Family history:* Father and mother died of tuberculosis of lungs; only child. *College course:* Physical. *Personal data:* No record.

HAM.

ROBERT L. HAMMOND; born Oct. 1, 1897; home Derby, Connecticut; age 20 years; height 184 cm.; nude weight 75.0 kilos. *Family history:* Negative. Has two brothers who are thin; one sister healthy. *College course:* Physical. *Personal data:* Can eat no fruit or jelly, as he says he can not keep them down; was not asked to eat them.

KIM.

HAROLD L. KIMBALL; born Feb. 11, 1893; home Waltham, Massachusetts; age 25 years; height 176 cm.; nude weight 61.9 kilos. *Family history:* No obesity or tuberculosis. One brother, thin. *College course:* Secretarial. *Personal data:* Jan. 5, 1918, served as subject in Boston first time in place of *Lon*. Jan. 21, said "It is a long way up here (4th floor of Laboratory); I feel a little weak."

LON.

ROBERT H. LONG; born March 14, 1896; home Brooklyn, New York; age 22 years; height 179 cm.; nude weight 66.8 kilos. *Family history:* Mother "rather stout"; dead. Father normal. Only child. No tuberculosis in

family. *College course:* Physical. *Personal data:* Jan. 5, 1918, ill and not present in Boston; place taken by *Kim.* Jan. 15, observed by one of us in gymnasium drill and noted as doing as well as average of class.

SCH.

JOHN SCHRACK; born Oct. 3, 1888; home Reading, Pennsylvania; age 29 years; height 166 cm.; nude weight 68.6 kilos. *Family history:* Family all thin, this subject being the heaviest one in the family. Four brothers and one sister, normal. No tuberculosis. *College course:* Physical. *Personal data:* Jan. 5, 1918, served as subject in Boston first time, taking place of *Mac.* Jan. 21, somewhat tired. *Physical activities:* Jan. 22, 1918, reported as not losing much weight, because he is less active.

LIV.

ALFRED LIVINGSTONE; born May 23, 1899; home Paterson, New Jersey; age 18 years; height 161 cm.; nude weight 60.5 kilos. *Family history:* All members of his family are short, but of average weight. Three brothers, all short. No tuberculosis. *College course:* Physical. *Personal data:* No record. *Physical activities:* Jan. 15, 1918, took part in public demonstration of Japanese and American wrestling in gymnasium. Like *Pea.*, the round with his opponent was a tie. The time was short, but no inferiority was apparent with *Liv.* Jan. 24, janitor remarked that the boys were not as they used to be, for usually he had only to ask for help and he had all he wanted. He referred to *Wil* and *Liv* in particular, who said they could not work, as they did not feel like it.

SNE.

CHESTER D. SNELL; born Nov. 24, 1895; home Canajoharie, New York; age 22 years; height 175 cm.; nude weight 72.3 kilos. *Family history:* Negative. *College course:* Secretarial. *Personal data:* Operation for correction of deviated septum from nasal partition, November 10, 1917. Did not go to bed, but felt weak for first 7 days. Afterwards only discomfort was due to rubber splint in nose, which was worn 4 weeks.

THO.

GEORGE H. THOMPSON; born Feb. 18, 1894; home Poughkeepsie, New York; age 24 years; height 179 cm.; nude weight 62.0 kilos. *Family history:* Negative. *College course:* Secretarial. *Personal data:* Captain of Squad B.

VAN.

FLOYD M. VAN WAGNER; born Mar. 27, 1894; home Hyde Park, New York; age 24 years; height 179 cm.; nude weight 67.3 kilos. *Family history:* All stout in father's family. Three brothers and one sister normal. Subject the heaviest in the family. No tuberculosis. *College course:* Physical. *Personal data:* No record.

WIL.

ELTON L. WILLIAMS; born Oct. 31, 1898; home Chelsea, Massachusetts; age 19 years; height 164 cm.; nude weight 58.5 kilos. *Family history:* Father weighed 250 pounds 10 years ago, weighed 200 pounds 5 years ago, weighs now 189 pounds. An aunt and a cousin died of tuberculosis. *College course:* Physical. *Personal data:* Jan. 24, 1918, see remark made by janitor in data for *Liv.*

The following subjects, as explained in their histories, served as members of Squad B for only a part of the time, and not during the weeks of diet reduction with this squad:

McM.

HARRY T. MCMICHAEL; born Sept. 18, 1897; home Belleview, Ohio; age 20 years; height 169 cm.; nude weight 67.6 kilos. *College course:* Secretarial. *Personal data:* Succeeded *Kon*, who was transferred to Squad A. Came to Boston with Squad B Nov. 3–4, Nov. 17–18, Dec. 15–16, and Jan. 5–6. Jan. 7, was ill in the forenoon, but at $7^h30^m$ p. m. felt better; temperature 101.3° F. Excused from further service on squad, as his parents refused to sign a permit for him to join in the diet reduction, and he had suffered from a stomach trouble for the previous 10 days. Succeeded by *Kim*.

LEO.

CLINTON S. LEONARD; born Apr. 27, 1897; home East Taunton, Massachusetts; age 21 years; height 183 cm.; weight 77.5 kilos. *College course:* Secretarial. *Personal data:* Substituted for *Fis* (who was ill) on the visit of Squad B to Boston, Dec. 15–16.

MAC.

ANGUS J. MACDONALD; born Sept. 19, 1891; home Cambridge, Massachusetts; age 26 years; height 174 cm.; nude weight 66.5 kilos. *College course:* Physical. *Personal data:* Served in Squad B on visits to Boston Oct. 6–7, Nov. 3–4, Nov. 17–18, and Dec. 15–16; later called to the Naval Reserves and succeeded by *Sch*.

## PROGRAM OF RESEARCH.

The research began with the fundamental question of the selection of subjects, the various requirements and degree of personal integrity demanded of the men limiting our field of selection greatly. Pending the actual selection of subjects, a large amount of preliminary work was done in getting together apparatus for studying the respiratory exchange and gas analysis and planning for the transportation of a considerable amount of material to Springfield. As previously stated, the selection of men was based in part upon physical qualifications and intellectual ability, and none of the men in Squad A were accepted until Dr. Chapin had been convinced that they were in good physical condition, according to clinical standards. This squad was placed at a special table and allowed to eat *ad libitum* for several days, so that the normal food consumption of the men prior to restriction might be determined. In this preliminary period the food was carefully aliquoted, sampled, and prepared for analysis. The following instructions were given Squad A and in somewhat revised form to Squad B:

The highly scientific character of this research and its magnitude are such as to demand from all connected with the work, either as subjects or as assistants and collaborators, an honest, faithful and accurate service ever maintained above reproach.

1. The subject must be in good health and confident of continued good physical condition under usual conditions of living.

2. He will sign an affidavit of his willingness to subscribe to all the requirements of the research.

3. He will promise uninterrupted service and cooperation during the entire period of observation and will not seek to be released from his responsibilities as a subject until the completion of the research unless compelled to do so by

major causes, such causes to be declared justifiable by the squad physician (a Springfield physician) or by a committee of the faculty. This period is to begin on Wednesday, Sept. 26, 1917, and end by Christmas, 1917.

4. Provision is to be made for the possibility of continuing the observations from 2 to 3 weeks longer if necessary. As this is likely to interfere seriously with the plans of some subjects during the Christmas vacation, it is possible that some way may be provided to meet the requirements of the research and still allow subjects to absent themselves during the usual holiday period.

5. The subjects will conform to the usual modes of living as regards work, exercise, diet (except as restricted) and sleep. No radical change in the ordinary daily life of the subject is permitted.

6. The subject will submit to a reduction in the daily food allowance sufficient to induce a loss of 10 per cent or more of body-weight in as short a time as possible, and also to maintain this acquired reduction in weight until the end of the test period.

7. The food will be served at a table reserved for the squad of subjects in Woods Hall dining room and will consist of the regular bill of fare for all students of the college.

8. It is desired that all portions of the food served be eaten completely. If not, the person in charge of the serving must be notified and will make a record of the food not eaten and, if necessary, collect it for analysis. It is supposed that when the ration is reduced the subjects will have no difficulty in eating the entire ration served.

9. The subject will not eat or drink anything whatsoever outside of the regular three meals served under supervision.

10. Water only in reasonable quantity is allowed at any time.

11. The subject must clearly understand that under the conditions of the research, the partaking of ice cream, fruit, peanuts, popcorn, etc., as well as sodas or drinks of any kind, unless intentionally served as a part of the regular allowance, is absolutely prohibited. The moderate chewing of gum is not prohibited.

12. It must, however, be understood that any breaking of this most important rule should be promptly reported, as by so doing the seriousness of the offense can be in part minimized.

13. *Collection of the urine:* (*a*) *All* urine voided will be continuously collected for exact periods of 24 hours each in properly labeled bottles which will be provided for the purpose. (*b*) Each 24-hour collection will be completed daily at $5^h30^m$ a. m. and placed at the disposal of the collector in charge at the place indicated for this. (*c*) No urine should be lost. Accidental losses must be prevented. If any occur they must be carefully noted and the quantity lost reported as accurately as possible the same day. (*d*) The loss of urine during defecation will be prevented by the simultaneous use of a urine-collecting bottle. (*e*) If urination is to occur away from the college premises the subject must take with him a bottle to receive the urine passed, which is to be added to the day's collection. (*f*) The collection of urine at the time the squad goes to Boston will not be interrupted until Sunday morning. Provision for this must be made as needed. The collection of urine on the Sundays in Boston will be omitted according to instructions given elsewhere.

14. *Collection of feces during weekly digestion period:* (*a*) Each Monday morning at breakfast with the first mouthfuls of food eaten, two or three gelatin capsules containing charcoal or carmine are to be swallowed. They will likewise be given with the first meal on Thursday morning. (*b*) Collect all the stools from Monday until the collector in charge will have notified

you that the charcoal given on Thursday morning has made its appearance in the stools. Under ordinary circumstances this will occur on Friday or perhaps not until Saturday.

15. *Trips to Boston:* (a) On Saturday afternoon, Sept. 29, and every two weeks hereafter, the squad will be taken to Boston. (b) On arriving a regulation supper will be served at a restaurant and the squad then conducted to the Nutrition Laboratory. (c) The evening will be spent in making various tests and taking measurements on the subjects. (d) The squad will retire and sleep in a large chamber constructed for the purpose of estimating the basal metabolism of its occupants. (e) Breakfast will be served at the laboratory on Sunday morning, after which the squad will be free to spend the day as it desires with the understanding that: (1) A low ration diet will be adhered to at noon and evening. (2) No urine need be collected from $5^h30^m$ a. m. Sunday until $5^h30^m$ a. m. Monday. This period, in which urine is *not* to be collected, ends with and includes the emptying of the bladder at exactly $5^h30^m$ a. m. each Monday. The first passage of urine to be again collected will be the first urination following that of $5^h30^m$ a. m. which is discarded only on each Monday morning.

16. *Respiration tests:* Subjects will be numbered from 1 to 12. Nine subjects will be examined daily according to a schedule to be made later. These tests will be made before breakfast every day except on the Sundays when the squad is in Boston. The time for these tests will be set so as not to interfere with the regular class work of the students.

In accordance with this agreement no food other than that served at table could be eaten. The men were particularly cautioned against the consumption of candies, peanuts, ices, etc., to which they were more or less accustomed. The following measurements were made for the most part with Squad A and also with Squad B during diet restriction:

*Urine and feces.*—Twenty-four hour amounts of urine were collected and the specific gravity and total nitrogen determined. To note the possibility of digestive disturbance, feces were collected at various intervals throughout the test. The nitrogen and total energy of the feces were determined, these supplying a measure of the digestibility of protein and total calories.

*Body-weight.*—As the foremost index of body condition and state of nutrition, body-weights were recorded under standard conditions, that is, with the subject nude, in the post-absorptive state, with an empty bladder, and without the previous drinking of water. Each weight was checked, not only by a member of the squad, but by a representative of the Nutrition Laboratory, and the date and time recorded.

*Body-surface measurements.*—To serve the dual purpose of giving a record of the changes in body-surface and a general index of the physical state, a series of body-surface measurements was made according to the method of Du Bois. These measurements were supplemented by anatomical photographs taken at frequent intervals throughout the test.

*Records of activity.*—No one factor plays a greater rôle in the consumption of energy than muscular activity. As the simplest index,

crude though it may be, the pedometer was used. Furthermore, the men were frequently questioned as to their extraneous physical activities other than normal. During certain periods a schedule of the actual activities during a period of one week was obtained.

*Pulse measurements.*—The pulse is the best general index of the metabolic level; hence every effort was made to secure pulse measurements as frequently as possible, but under controlled and comparable conditions. These included observations with the subject lying quietly in the post-absorptive condition, sitting during meals, standing and in the post-absorptive condition, lying quietly before and after riding on a bicycle ergometer, standing before and after walking experiments, and during walking. Wrist counts were supplemented by standard electrocardiograms and electrocardiograms during exertion.

*Clinical examinations.*—Clinical examinations of Squad A and of Squad B during diet restriction were carefully made by Dr. Goodall. These included examinations of the heart, lungs, reflexes, glands, and blood pressure.

*Blood examination.*—Somewhat late in the test arrangements were made, through the kindness of Dr. George R. Minot of Boston, for a series of careful blood examinations. We were so fortunate as to secure the cooperation of Miss Anna L. Gibson and her associate, Miss M. B. Conover, who made the blood examinations on nearly every visit of the squads to Boston after December 19.

*Body temperature.*—Each morning prior to the gaseous metabolism experiments in Springfield, the temperature was taken in the mouth with a clinical thermometer, simply to show the absence of fever. For true physiological measurements we relied upon the temperature taken in the rectum at the end of the night experiments in the large chamber in Boston. To give a possible suggestion as to changes in skin temperature, electrical measurements of surface temperature were taken during the latter part of the test.

*Gaseous metabolism.*—The gaseous metabolism was measured under four different conditions: (1) With the subjects lying quietly and in the post-absorptive condition, by means of the respiratory-valve apparatus and the portable respiration apparatus; (2) with the subjects lying asleep after a light supper, in a night experiment with the group respiration chamber; (3) with the subjects in the post-absorptive condition and in the standing position; and (4) with the subject walking on the treadmill in the treadmill chamber. The first two measurements gave an indication of the basal metabolism of the subjects, the third provided a base line for the metabolism during walking, and the fourth supplied evidence of the energy requirements for the ordinary activities of the day. The fourth series of observations also gave information as to the effect of a reduced diet upon the efficiency of the men in ordinary physical activity.

*Psycho-physiological measurements.*—An extended series of psycho-physiological measurements was made by approved methods in both group and individual tests whenever the subjects visited Boston. Full details are given of the various tests in later sections.

## WEEK-END PROGRAM.

To illustrate the personal demands made upon the subjects as a result of these observations, a typical week-end program for Squad A is given. Beginning early Friday morning at Springfield, the activities of the squad are shown until the conclusion of the tests on Sunday in Boston.

*Friday:*

$5^h30^m$ a. m. Nine men ready for respiration experiments; 7 men portable respiration apparatus; 2 men respiratory-valve apparatus. Routine of experiments: Bladder emptied; weighed (stripped); lay on couch for preliminary period; mouth temperature taken; two periods (10 to 15 minutes each) on respiration apparatus; pulse and respiration rates taken during experiment; alveolar air determinations made for 2 men on respiratory-valve apparatus.

$6^h45^m$ a. m. Breakfast; pedometer readings recorded.

$9^h30^m$ to $11^h30^m$ a. m. Bicycle ergometer experiments with Professor Johnson; 5-minute periods; subjects, *Bro, Gul, Gar.*

$12^h10^m$ p. m. Dinner; pulse-rate counted at wrist by subject (sitting).

$1^h30^m$ to $4^h30^m$ p. m. Bicycle ergometer experiments with Professor Johnson; subjects, *Pec, Vea, Can, Moy, Spe, Mon, Tom, Kon, Pea.*

6 p. m. Supper; pulse-rate counted at wrist by subject (sitting).

*Saturday:*

$5^h30^m$ a. m. Nine men ready for respiration experiments; regular routine followed.

$7^h30^m$ a. m. Breakfast.

$9^h10^m$ a. m. Train Springfield to Boston.

$11^h36^m$ a. m. Squad arrived in Boston.

12 (noon). Standard dinner at restaurant.

5 p. m. Standard supper at restaurant.

$5^h45^m$ p. m. Squad arrived at Nutrition Laboratory.

6 to 7 p. m. Group psychological tests in library at Laboratory. For order of tests see section on technique (page 139) and program of research (page 149). Pulse-rates (sitting) during psychological tests; skin temperature measurements at end of psychological tests.

7 to $10^h30^m$ p. m. Individual psychological measurements in psychological laboratory (60 to 70 minute period); measurements given to 4 men simultaneously. When not occupied with psychological tests, the men were given the following: Clinical examination by Dr. Goodall; blood tests by Miss Gibson; Du Bois body-surface measurements; profile photographs; 5-minute practice in walking on treadmill.

$10^h00^m$ to $10^h30^m$ p. m. Men went to bed in the group respiration chamber as soon as all had finished the tests previously mentioned.

$10^h45^m$ p. m. Men all in bed, cover of group chamber closed; preliminary period of experiment began.

$11^h15^m$ p. m. Respiration experiment proper began; periods approximately 30 minutes long throughout the night.

*Sunday:*

5 a. m. Respiration experiment ended.

$5^h50^m$ a. m. Cover taken off group chamber.

6 a. m. Routine for each subject as follows: Rectal temperature and pulse-rate determined by observer with subject lying; subject then rose, emptied bladder, was weighed nude, dressed, and received standard laboratory breakfast.

$6^h30^m$ to 9 a. m. Individual psychological measurements given to subjects, three men at a time, in 25-minute periods. Men then free for the rest of the day.

On Jan. 6 and 28 for Squad B and Feb. 3 for Squad A, the program for Sunday morning was changed to include experiments on the treadmill and portable respiration apparatus. On these dates the Sunday morning program was as follows:

$3^h50^m$ a. m. Respiration experiment in group chamber ended.

4 a. m. Cover taken off group chamber.

$4^h15^m$ a. m. Rectal temperature and pulse-rate measured as before, also bladder emptied; first man weighed nude on second floor of Laboratory; he then dressed, was given a glass of water to drink, and went to third floor of Laboratory for experiments. Same routine followed for other men in turn.

$4^h25^m$ a. m. to 1 p. m. Standing experiments with portable respiration apparatus, and walking experiments with treadmill apparatus; men called in turn at intervals of 20 to 30 minutes.

*Routine of experiment with portable respiration apparatus:* Two experimental periods, each 12 to 15 minutes long; pulse and respiration rates taken during experiment; blood pressure taken at end of experiment.

*Routine of treadmill experiment:*[1] Electrodes adjusted and pulse-rate taken in hall outside of treadmill room; pulse-rate, sitting in treadmill room; pulse-rate, standing on treadmill; pulse-rate, transition standing to walking. *Preliminary period:* 4 minutes walking on treadmill, with cover off of chamber 2½ minutes. *Main period:* Walking on treadmill, with cover on chamber, 20 minutes; electrocardiograms taken and approximate measurement of respiration rate made during 6th, 12th, and 24th minutes of walking. Visual counts of deflections of galvanometer each minute made during preliminary period and main period of experiment; total distance traveled recorded; total number of steps recorded. *After experiment:* Pulse-rate taken, transition walking to standing; successive blood-pressure measurements immediately at end of walking for period of 2 minutes; subject weighed with electrodes and dressed as on mill; blood pressure and radial pulse, sitting, for 10 minutes; strength of grip, but no other psychological measurements. Men dismissed as each finished the last test.

## CHRONOLOGICAL HISTORY OF LOW-DIET RESEARCH.

To give a general idea of the research and the sequence of events, a chronological history, for both Squads A and B, is included here for the period from September 22, 1917, to May 22, 1918, inclusive.

*September 22.* Shipment of apparatus and general supplies from Boston to Springfield.

[1] Transition pulse-rate, standing to walking, and walking to standing, visual counts of the galvanometer, and blood-pressure measurements immediately at the end of walking not taken with Squad B on January 6.

*September 24.* General call for volunteers.

*September 25.* Unpacking and installation of apparatus.

*September 27, Squad A.* First experiments in Springfield with respiratory-valve apparatus and portable respiration apparatus and first records of pulse-rate; first collection of urine.

*September 29, Squad A.* Came to Boston (*Kon* excepted). Came to Laboratory immediately after prescribed evening meal and took psychological tests for first time in following order:

Group tests in library:
- Accuracy in tracing between irregular parallel lines.
- Memory span for 4-letter English words.
- Addition of one-place numbers for a period of 10 minutes.
- Discrimination for specified number groups on a printed page.
- Discrimination for the pitch of tone.

Individual tests in psychological laboratory and adjoining rooms:
- Sensory threshold for electric shock.
- Latency, amplitude, and refractory period of the patellar reflex.
- Speed of the finger movements.
- Efficiency in traversing a right-angle maze.
- Efficiency in performing certain clerical tasks.

In addition to psychological measurements, other measurements were: First Du Bois surface measurements; first profile photographs; first experiment in group respiration chamber.

*September 30, Squad A.* In Boston at Laboratory part of morning. First record of body-weight.

*October 1 to 3, inclusive, Squad A.* Normal diet at training table; food portions weighed, sampled, and samples analyzed. First digestion period for collection of feces. (*Pec* not included; he was always irregular in these periods.)

*October 2, Squad A.* Physical examination, Dr. Chapin (*Can*, *Gul*, and *Kon* excepted).

*October 4, Squad A.* First reduction in diet.

*October 6, Squad A.* Pedometers used from this date to end of experiment. First use of bran in diet.

*October 6, Squad B.* Came to Boston. At Laboratory immediately after prescribed evening meal and took psychological experiments as outlined for Squad A on September 29. *Kon* and *Mac* included in these measurements, but *McM*, *Kim*, and *Sch* not included. First experiment in group respiration chamber.

*October 7, Squad B.* First record of body-weight (*McM*, *Kim*, and *Sch* excepted).

*October 8–11, inclusive, Squad A.* Second digestion period for collection of feces.

*October 9, Squad A.* Affidavit signed.

*October 10, Squad A.* Began using margarine instead of butter for some of the meals.

*October 13, Squad A.* Came to Boston; supper at restaurant. At Laboratory after evening meal; second series psychological tests. Added to tests:
- Sensory threshold for visual efficiency (acuity).
- Reaction time for speaking 4-letter words.
- Continuous discrimination and reaction in finding serial numbers.

First clinical examination, Dr. Goodall; second experiment in group respiration chamber.

*October 14, Squad A.* In Boston; at Laboratory part of morning. Meals uncontrolled on this date, except for breakfast at Laboratory.

*October 16, Squad A.* Topped milk, *i. e.*, part of cream removed, used on this date and subsequently; whole milk used previous to this date.

*October 17–20, inclusive, Squad A.* Third digestion period for collection of feces.

*October 19, Squad A.* First bicycle ergometer experiments made by Professor Johnson; made on Mondays and Fridays throughout research with Squad A.

*October 24, Squad A.* Last day *Fre* ate at training table.

*October 24, Squad B.* First bicycle ergometer experiments with Professor Johnson; made on Wednesdays with Squad B throughout research.

*October 27, Squad A.* Came to Boston; supper at restaurant. Psychological tests previously described, also strength of grip. *Kon* served in place of *Fre.* Second clinical examination, Dr. Goodall (first for *Kon*); second profile photographs (first for *Kon*); first Du Bois body-surface measurements for *Kon.* Third experiment in group respiration chamber (11 men only, *i. e.*, without *Kon*).

*October 28, Squad A.* In Boston; at Laboratory part of morning. Meals uncontrolled on this date, except for breakfast at Laboratory. First Sunday morning program for psychological measurements; individual measurements as follows:

Changes in pulse-rate occasioned by short periods of exertion.
Reaction time for turning the eye to a new point of regard.
Speed of the eye movement.
Two finger movement records, like those taken in evening.
Strength of grip.

*October 30, Squad A. Kon* at training table for first time.

*Oct. 31 to Nov. 3, inclusive, Squad A.* Fourth digestion period for collection of feces.

*November 3, Squad A.* First use of currant jelly to replace more or less butter in diet.

*November 3, Squad B.* Came to Boston. Evening psychological tests. *McM* served as subject in place of *Kon*, transferred to Squad A. Second experiment in group respiration chamber.

*November 4, Squad B.* In Boston; at Laboratory part of morning. First Sunday morning program of psychological measurements. (See Oct. 28 for outline.)

*November 10, Squad A.* Came to Boston; dinner and supper at restaurant (*Pea* had dinner in Springfield). Regular evening psychological tests. Third clinical examination, Dr. Goodall. Individual 5-minute practice walking on treadmill in preparation for subsequent walking experiments. Questioned in evening regarding introspection on diet, hunger pains, physical endurance, etc. Fourth experiment in group respiration chamber.

*November 11, Squad A.* In Boston; at Laboratory part of morning. First rectal temperature measurements, with subject lying in group respiration chamber after night experiment. Regular morning program psychological measurements. Meals uncontrolled on this day except for breakfast at Laboratory.

*Nov. 12 to 17, inclusive, Squad A.* Fifth digestion period for collection of feces.

*November 13, Squad A.* Use of bran muffins begun.

*November 17, Squad B.* Came to Boston; supper at restaurant. Regular evening psychological tests. Individual 5-minute practice walking on treadmill. Third experiment in group respiration chamber.

*November 18, Squad B.* In Boston; at Laboratory part of morning. First rectal temperature measurements, with subject lying in group respira-

respiration chamber; others taken on some of the men while they were in reclining position in the psychological laboratory.

*Dec. 20, 1917, to Jan. 6, 1918, inclusive.* Christmas recess. *Squad A.* Urine collected daily by *Gul;* except on December 22–30 and December 31—January 1 by *Pec.*

*January 5, Squad B.* Came to Boston; supper at restaurant. Regular evening psychological measurements. *McM* had had trouble with stomach previous 10 days; *Lon* ill, substitute, *Kim; Mac* called to Naval Reserves and *Sch* took his place. Regular psychological measurements on two new subjects, *Kim* and *Sch.* First clinical examination, Dr. Goodall; first blood examination, Miss Gibson; first Du Bois body-surface measurements; first profile photographs. Fifth experiment in group respiration chamber.

*January 6, Squad B.* In Boston; at Laboratory part of morning. First body-weights for *Kim* and *Sch.* First standing experiments with portable respiration apparatus and first pulse records standing. First treadmill walking experiments. No psychological measurements in morning, only strength of grip. Standing and treadmill experiments made serially, the routine for the first subject, which was typical of the others, being as follows: First subject called at about $4^h00^m$ a. m.; when weighed and dressed, he served two periods as subject for standing experiment, with pulse records during standing; at 5 o'clock he was ready for the 24-minute treadmill experiment; pulse record made 5 minutes after walking experiment ended.

*January 7, Squad B.* First urine collections by all but *How* and *Lon.* *Kim* now serving in place of *McM.*

*January 7, Squad A. Can, Gar, Gul, Mon, Pea, Pec,* and *Vea* returned from Christmas recess; at table for all three meals on this day. *Moy* at dinner and supper, but breakfasted elsewhere.

*January 8, Squad A. Bro* returned and at training table.

*January 8, Squad B.* First urine collections by *How* and *Lon.* First day of controlled, reduced diet.

*January 9, Squad B.* Affidavit signed

*January 11, Squad A. Kon* and *Tom* returned; ate only supper at training table. *Spe* did not return to the squad.

*Jan. 11 to Feb. 2, Squad A.* Exercise records kept during this period.

*Jan. 11 to Feb. 3,* Exercise records kept by an uncontrolled squad of fellow students.

*January 11 to 28, Squad B.* Exercise records during this period.

*January 12, Squad A.* Came to Boston; dinner and supper at restaurant. *Tom* had dinner in Springfield. Regular evening psychological program. Individual 5-minute practice on treadmill. Seventh clinical examination, Dr. Goodall. Second blood examination, Miss Gibson. Eighth experiment in group respiration chamber.

*January 13, Squad A.* In Boston; at Laboratory part of morning. Regular morning psychological program. Meals uncontrolled except breakfast at Laboratory. This was the last Sunday of uncontrolled meals. Excess eating on this date and consequent gain in weight led to subsequent sharp reduction in diet for a few days for *Kon, Bro,* and *Gar.*

*January 13, Squad B.* Came to Boston; lunch on train; supper at restaurant. Regular evening psychological program. *Kim* serving in place of *McM* and *Sch* in place of *Mac.* Individual 5-minute practice walking on treadmill. Second blood test, Miss Gibson. Second clinical examination, Dr. Goodall. Sixth experiment in group respiration chamber.

samples, *a* and *b*, could be compared and notation made of marked discrepancies, if any existed. Theoretically both samples should have dried to essentially the same weight.

FIG. 1.—Drying oven.

The walls and doors of this oven are of asbestos board and the shelves are of strong wire mesh. A rose burner in the air intake at the bottom furnishes the heat; the temperature of the oven is indicated by a thermometer at the side. Ventilation is secured by a fan placed in the exit pipe above the oven.

## METHODS OF ANALYSIS.

### URINE.

Observations on the urine were confined to the crude observations of specific gravity with a standard spindle and to the exact determination of nitrogen by the Kjeldahl process. The Laboratory is well supplied with automatic pipettes, digestive apparatus, and stills for the most rapid work. The 1,000 or more urine analyses involved in this research were made exclusively under the supervision of Miss Elizabeth B. Babcock, and were carried out with extraordinary fidelity, rapidity, and accuracy. In this work she was assisted by Miss Marion L. Baker and Mr. Harry Silverman.

FOODS AND FECES.

The dried samples of foods and feces were analyzed for total nitrogen by the Kjeldahl process. Here again the nitrogen content of samples *a* and *b* supplied a check upon each other.

HEAT OF COMBUSTION.

To obtain an energy balance, it was necessary that we should find the actual calories in the intake of food. Of the output it was possible for us to determine only the calories in the feces. Since, however, there are reasonably constant standard factors for computing the calories from the percentage of nitrogen in urine, we resorted to this method rather than attempt to dry down the 1,000 or more samples of urine obtained in the research and determine the heats of combustion with the bomb calorimeter. The daily output of energy in urine was found by multiplying the total number of grams of nitrogen by the factor 8.0. The energy as thus calculated was almost invariably somewhat under 100 calories, so that the error due to the method cannot at best be an appreciable portion of the total energy under consideration for the day.

The heats of combustion of the feces and dried foods were determined with a bomb calorimeter of the Kroker type in an adiabatic calorimeter. This calorimeter was developed in the Nutrition Laboratory and promotes rapid operation.[1] The technique was finally so adjusted that after the various dried pellets of feces and food had been prepared and weighed and placed in nickel capsules, Miss M. A. Corson and her assistant were able to determine and compute four heats of combustion per hour. This made it possible to complete this extensive series of determinations within a reasonable time.

Since the total nitrogen and calories were obtained, it was deemed unnecessary to make an exact apportionment of the energy of the intake between protein on the one hand and fat and carbohydrate on the other. It is perfectly possible, knowing the total caloric value and nitrogen of the intake, to compute the calories due to protein. The remainder will be due to fat and carbohydrate. These were all mixed diets, with no special dietary adjustments other than decrease in the portions served. It hardly seemed advantageous to determine the fat in the food intake; indeed, the time requirement for such determination for all of the samples would alone preclude this additional work. A few special fat extractions were made which will be mentioned in the text from time to time, but there was nothing to indicate that exact information regarding the relative proportion of calories from fat and carbohydrate would have a special significance in the discussion of the results.

[1] Benedict and Higgins, Journ. Am. Chem. Soc., 1910, 32, p. 461.

oxygen consumed by means of a direct reading of the level of the spirometer bell at the beginning and end of an experiment.

After leaving the air-purifying bottles, the air passes through a tube to the mouth of the subject. The expired air, containing carbon dioxide, is drawn through a large-caliber tube to the spirometer, from which it is whirled by the blower through the purifying bottles, and thence returned to the subject for rebreathing. The connections with the subject are shown in figure 2 and the general installation and details of the air-circuit in figure 3.

### ROTARY AIR-IMPELLER.

The portable respiration apparatus is a recent development of the universal respiration apparatus,[1] but has many striking similarities to the early "oxygénographe" of Fredericq[2] and the later device of Krogh.[3] In at least one main particular, however, this apparatus differs from the earlier forms in that the air is circulated not by the lungs of the subject, but by an electrically-driven fan. There are no valves to be actuated by the lungs, and the fan does all the work of

[1] Benedict, Deutsch. Arch. f. klin. Med., 1912, 107, p. 156; see also Am. Journ. Physiol., 1909, 24, p. 345.

[2] Fredericq, Arch. de Biol., 1882, 3, p. 687; also Éléments de Physiologie Humaine, Ghent and Paris, 1888, 2d ed., p. 141.

[3] Krogh, Skand. Arch. f. Physiol., 1913, 30, p. 379.

trol within one 12 to 13 minute period, and in one 15-minute period it is possible to secure readings for three determinations of the oxygen consumption.

At the conclusion of a period, oxygen is again admitted, the initial position of the spirometer read, connections made with the subject as before, and a new period begun. All of this can be carried out without stopping the motor. If, during the first period, a larger amount of oxygen has been introduced than is actually consumed, a little more air can be rejected by turning the 3-way valve and lifting slightly the counterpoise. It is thus seen that the oxygen consumption may be approximately measured by the fall of the spirometer and the actual computation of this contraction in volume be completed by using the data obtained regarding the temperature and barometric pressure.

### METHOD OF CALCULATING OXYGEN CONSUMPTION.

The method of calculating the amount of oxygen consumed in one period of an actual experiment may be illustrated by period 1 of the experiment with *Bro* on January 8, 1918. (See table 3.) In the two earlier periods of this experiment, the mask was employed; in this period the mouthpiece was used, and two sets of records were made, one being included in the other. The intermediate measurement[1] is designated for convenience "period *1a.*"

TABLE 3.—*Calculation of oxygen consumption in experiment with the portable respiration apparatus.*

Subject: *Bro.* Date of experiment, Jan. 8, 1918.
Apparatus used: Portable respiration apparatus No. 1. Breathing appliance: Mouthpiece.
No. of period: 1, 1*a*. Duration period 1....... 15′16″ (15.27′)
Period 1 began 6 a. m. Duration period 1*a*...... 8′ 8″ ( 8.13′)

| *Height of spirometer bell.* | Period 1. | Period 1*a*. | *Temperature of spirometer.* | Period 1. | Period 1*a*. |
|---|---|---|---|---|---|
| Beginning...... | 984 mm. | 942 mm. | Beginning..... | 75 | 78 |
| End........... | 820 mm. | 853 mm. | End.......... | 82 | 80 |
| Difference...... | 164 mm. | 89 mm. | Av. (°F.)...... | 78.5 | 79 |
| | | | Av. (°C.)...... | 25.8 | 26.1 |

Barometer 740.6 mm.

| | *Logarithms.* Period 1. | Period 1*a*. |
|---|---|---|
| Difference in height of spirometer bell........................... | 2.21484 | 1.94939 |
| Volume per mm. height of spirometer bell....................... | 1.32056 | 1.32056 |
| To reduce to 0° C........................................... | 9.96071-10 | 9.96027-10 |
| To convert to 760 mm. pressure................................ | 9.98877-10 | 9.98877-10 |
| Decrease in volume at 0° C. and 760 mm. (oxygen consumed)...... | 3.48488 | 3.21899 |
| Duration of period............................................ | 1.18384 | 0.91009 |
| Oxygen consumed per minute.................................... | 2.30104 =200 c.c. | 2.30890 =204 c.c. |
| Correction for reduction of total vol. of air to 0° C. and 760 mm. (+1 c.c. for each rise of 1° F.)......................... | +7 | +2 |
| | 207 c.c. | 206 c.c |
| Average of two measurements of oxygen consumed per minute ... | 207 c.c. | |

[1] In this case but one intermediate period instead of two was recorded.

volume of air. Such computations have been made for 14 experiments in which from 198 to 272 c.c. of oxygen were used and with temperature fluctuations ranging from 3° to 19° F. It was found that the difference as a result of making this reduction corresponds to +1 c.c. of oxygen for each degree Fahrenheit of the rise in temperature during the measurement. It is therefore justifiable, for the sake of simplicity, to make an arbitrary correction by adding 1 c.c. of oxygen for each degree of the rise in temperature of 7° F. This gives a value of 207 c.c. of oxygen per minute consumed during the period of 15 minutes and 16 seconds.

The same method is followed in calculating the oxygen consumed during the intermediate measurement, *i. e.*, period *1a*. The agreement of the two measurements is excellent, 207 and 206 c. c. oxygen per minute.

### PRACTICAL USE OF THE APPARATUS.

From the foregoing description it will be seen that this apparatus dispenses with gas analysis and weighings. By reading the millimeter scale indicating the height of the spirometer bell, the thermometer in the top of the spirometer, and the barometer, we may obtain all the data required for rapidly computing oxygen consumption and heat production. The apparatus is designed particularly for the determination of the oxygen consumption, with special reference to clinical application. It can not be used for the determination of the respiratory quotient as a substitute for either the respiratory-valve method outlined by Dr. Carpenter (a closely fitting mask, Tissot valves, a carefully calibrated spirometer, good gas-analysis apparatus, and a good gas analyst) or the perfected form of the clinical respiration apparatus developed in the Nutrition Laboratory.[1] The portable respiration apparatus has, however, the advantages of portability, simplicity, and rapidity of operation, with a degree of accuracy in the determination of the oxygen consumption to meet the needs of practically all scientific work. It was particularly adapted for use in the low-diet research for simultaneously measuring the basal metabolism of seven young men each morning. Four of the apparatus employed for these observations are shown in figure 4 in position, with accompanying beds, in one of the laboratory rooms at the Young Men's Christian Association College, Springfield, Massachusetts.

### GROUP RESPIRATION APPARATUS.

While the universal respiration apparatus in its various forms permits the measurement of the metabolism of an individual, even when he is working to the limit of human endurance, it is practically limited to the measurement of a carbon-dioxide production not exceeding 2,700 to 2,800 c.c. per minute. As a matter of fact, this particular

[1] Benedict and Tompkins, Boston Med. and Surg. Journ., 1916, 174, pp. 857, 898, and 939.

## RESPIRATION CHAMBER.

Personal visits to Stockholm and Helsingfors and inspection of both the Scandinavian chambers led to material modification in the design for the chamber built in the Nutrition Laboratory. Thus it was seen that the height could easily be reduced. Second, the entrance to the chamber was best made from the top; fortunately the unusually high ceiling of the calorimeter laboratory made this change possible without difficulty. The calorimeter laboratory is provided with excellent automatic heating and cooling arrangements for maintaining uniform temperature. Hence no special appliances for heating the new respiration chamber were needed. As a matter of fact, it was found subsequently that cooling rather than heating was absolutely essential.

FIG. 6.—View of east end of group respiration chamber.

*a*, Inner wooden floor; $b_1$ and $b_2$, windows; *c*, suspension-rod supporting roof of chamber; *d*, step-ladder; *e*, hook for supporting ladder *d* when not in use; *f*, trap-door resting in groove *gg* when closed; *hh*, brine coil; *k*, rotary air impeller; *b*, opening into chamber for ingoing air; *m*, Bunsen burner for heating ingoing air; *n*, butterfly valve.

The details of construction of the respiration chamber are given in figures 6 and 7. Figure 6 shows the window (east) end of the chamber. A cross-section of the chamber in the longest dimension from west to east is represented in figure 7.

The respiration chamber has an inner lining of sheet metal, which is absolutely air-tight. As this inner lining required a substantial wooden backing to prevent unnecessary wear or play by the buckling of the sheet metal, a framework was built on the floor of the calorimeter room

from timber 4 inches square; this framework had a width of approximately 13 feet 3½ inches and a length of 17 feet 9½ inches. To this base were fastened the several uprights which were covered with a sheathing of ¾-inch matched lumber. The framework on the floor was then lined with galvanized iron, which extended up 10 inches on the wooden walls of the chamber, for it was believed that the greatest stress and wear would be borne by these parts. The rest of the inner metal lining was made from tinned sheet iron. The inner metal lining of the chamber has therefore a length of 17 feet, a width of 12½ feet, and a height of 7½ feet. The outside of the chamber was finished with ⅜-inch "compo board," which was painted. Between the compo board and the inner wooden wall is an air-space of 4 inches.

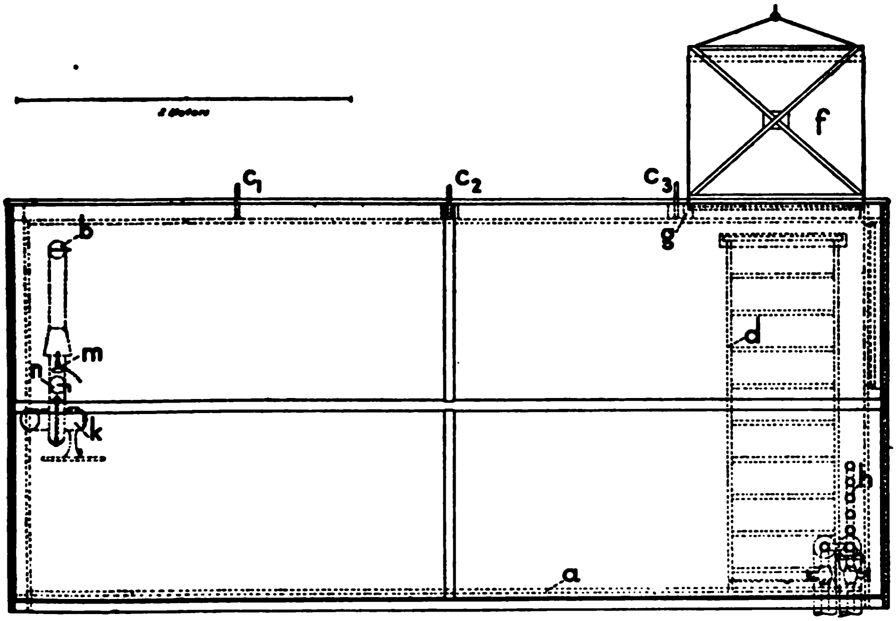


FIG. 7.—Cross-section of group respiration chamber from west to east.

*a*, Inner wooden floor; *b*, opening for ingoing air; $c_1$, $c_2$, and $c_3$, ¾-inch suspension-rods; *d*, step-ladder; *f*, trap-door; *g*, water-seal trough; *h*, brine coils; *k*, rotary air-impeller; *m*, Bunsen burner for heating ingoing air; *n*, butterfly valve.

To prevent excessive wear of the galvanized iron floor, it was necessary to install an inner wooden floor (*a* in figs. 6 and 7), which was made of ⅞-inch maple flooring, resting upon 2 by 4 inch wooden stringers, laid on edge. This floor was substantially made and well smoothed to secure a rigid base upon which groups of individuals could walk with freedom or perform severe muscular exercise. The original intention was to have the floor as nearly as possible air-tight, so as to consider as the flexible or movable portion of air inside the chamber only that above the floor. For this purpose a copper flashing was soldered to the bottom of the metal wall, turned in over the top of the maple flooring, securely tacked to the floor and filled in with shellac.

wind chest, *A*, shown in detail in figure 9. In the top of this wind chest are three openings. At the extreme right there is an opening, *B*, figure 9, provided with a water seal into which caps of various sizes can be set. The other two openings, each of 10 mm., lead directly into the center of the bottom of two cylindrical copper cans, $C_1$ and $C_2$. These openings were drilled in disks at the same time and hence are of exactly the same size, which was subsequently proved by most careful calipering. Each disk is attached with a threaded collar to a pipe in

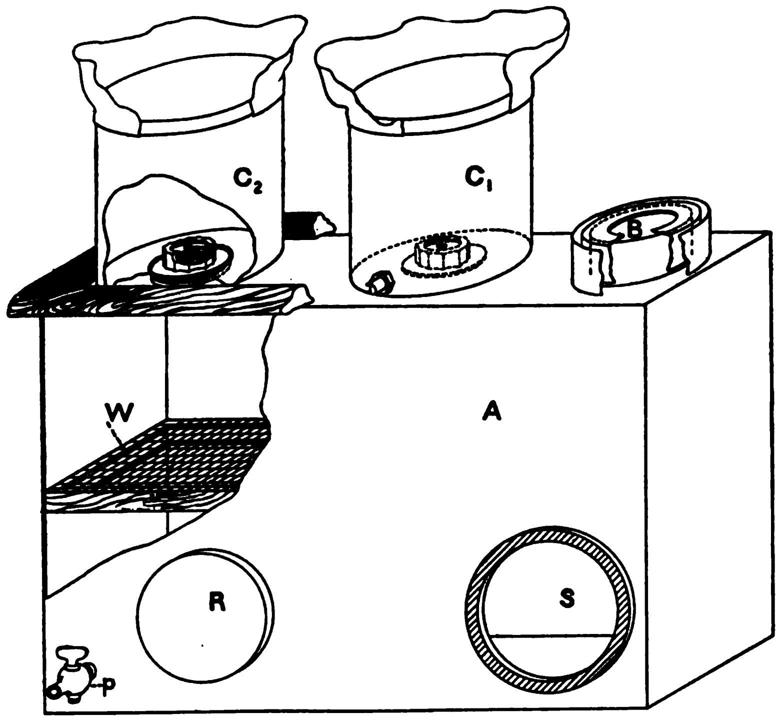


FIG. 9.—Detail of wind chest.

*A*, wind chest; *B*, opening to outside. $C_1$, $C_2$, cylindrical copper cans from which air is drawn by means of two Crowell blowers. *R*, hand hole; *S*, opening into wind chest for discharge from rotary air-impeller; *W*, wire screen; *p*, petcock for attaching manometer to obtain pressure in wind chest.

the top of the wind chest. Between the 10-mm. disks and this pipe are placed rubber gaskets, which insure tight closure. The details of this installation are given in figure 10, in which *a* is the brass disk with a 10-mm. orifice, *b* the collar, *c* the brass pipe soldered to the top of the wind chest, and *d* the rubber gasket. To attach the cans $C_1$ or $C_2$ to the top of the wind chest and secure an air-tight closure, a rubber gasket, *e*, is placed between the can and the wind chest and pressure applied by a threaded collar, *f*.

this covered pan air was continuously withdrawn through a series of U-tubes at such a rate that by the time the next sample was ready to be delivered into the pan the first sample had been practically all withdrawn.[1] By this method, however, air was but intermittently dis-

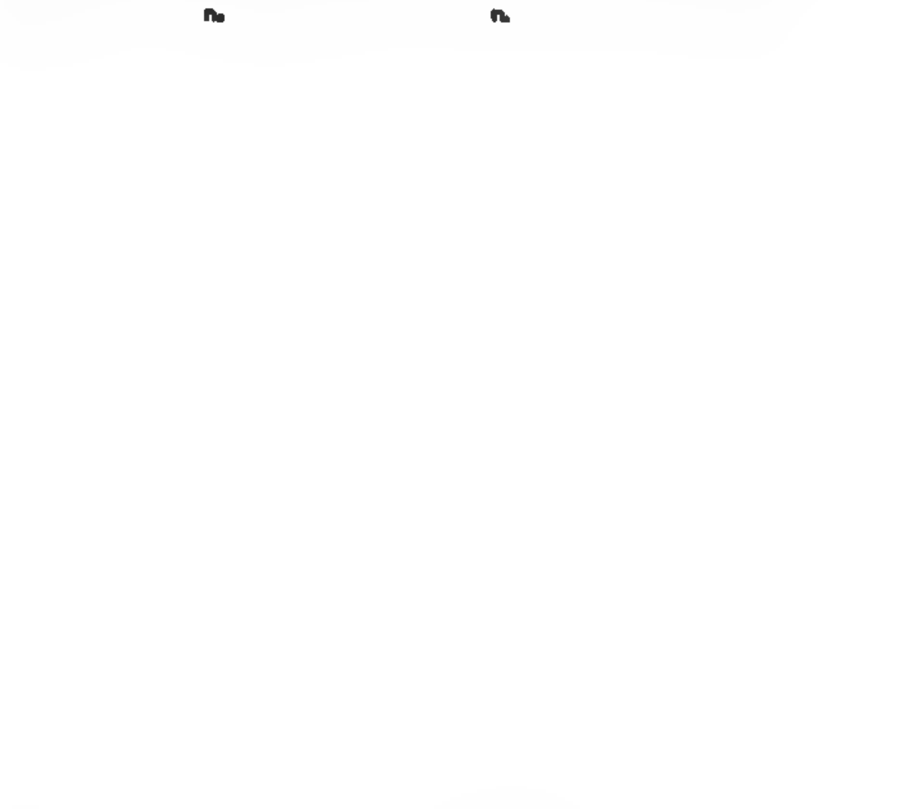


FIG. 13.—Details of device for regulating pressure inside of cylindrical cans above wind chest.

*A*, wind chest; *B*, opening for delivery of major portion of air to outside; $C_1$, $C_2$, cylindrical cans above wind chest; $b_1$, $b_2$, openings for delivery of air from $C_1$, $C_2$ to outside; the weights of the bathing caps on tops of cans $C_1$, $C_2$ are counterpoised by the springs, $s_1$, $s_2$, the tensions of which are regulated by the nuts, $n_1$, $n_2$; when the pressure inside of cans $C_1$, $C_2$ gets too low, the contact shown between disks $d_1$, $d_2$ is closed, and the current passing through this circuit draws down the telegraph sounder shown in fig. 11; this permits the opening of tube $m_1$ or $m_2$ (fig. 11) and by-passes a portion of the air, thus drawing less air from the can $C_1$ or $C_2$. In this way the amount of air drawn from $C_1$ or $C_2$ is regulated so that the air inside of either can is practically always at atmospheric pressure. $d_3$ is a disk for preventing the bathing cap from rising unduly.

charged into the pan and with a pump that, while not capable of exerting any great positive pressure, nevertheless could easily overcome the slight friction of the counterpoise weight of the rubber diaphragm. Our present problem, however, was to remove the air from the samp-

[1] Atwater and Benedict, U. S. Dept. Agr., Office Expt. Sta. Bul. 109, 1902, p. 27.

cally all instances corrected our periods for changes in the residual analysis, the analyses being for the most part made with the Sondén apparatus. Similarly, in check tests, in which the carbon dioxide was admitted to the large chamber from a steel cylinder and the carbon dioxide was determined in short periods, the residual analysis played a very important rôle, for the introduction of the carbon dioxide into the chamber was extremely irregular. On the other hand, with a group of normal men or women pursuing a certain definite procedure such as reading or walking, the carbon-dioxide production becomes very regular after a very short time. In certain instances the accuracy of the Sondén apparatus for finding the residual carbon dioxide was determined by having no ventilation in the chamber, analyzing the air at the start, introducing a certain amount of carbon dioxide, analyzing the air at the end, and comparing the carbon-dioxide content of the air at the beginning and the end of the test. This type of check also gave most gratifying results whenever used.

The humidity and temperature of the air inside the chamber were determined by the wet and dry bulb thermometer, easily read through the glass window. The method of calculation is indicated in detail for a single experimental period in table 4, and the summary of results of an entire night experiment in table 5.

TABLE 4.—*Typical calculation of a period with the group respiration chamber (12h32m—1h02m a. m. Oct. 7, 1917.)*

*Calculation of residual carbon dioxide in the chamber.**

| Observations. | At 12h32m a. m. | At 1h02m a. m. |
|---|---|---|
| Barometer | 768.60 mm. | 768.75 mm. |
| Temp. barometer | 20.0°C. | 20.0°C. |
| Temp. dry bulb | 18.7°C. | 18.9°C. |
| Temp. wet bulb | 15.3°C. | 15.4°C. |
| Per cent $CO_2$ | 0.191 | 0.195 |
| | Logarithms. | Logarithms. |
| $(p-e)/760$ | 9.99725–10 | 9.99733–10 |
| $1/1+0.00367t$ | 9.97117–10 | 9.97088–10 |
| Volume of chamber | 4.63925 | 4.63925 |
| Per cent $CO_2$ | 7.28103–10 | 7.29003–10 |
| Liters to grams | 0.29320 | 0.29320 |
| Total residual $CO_2$ | 2.18190 = 152.0 grams. | 2.19069 = 155.1 grams. |

Change in residual $CO_2$ = +3.1 grams.

*Calculation of carbon dioxide produced during the period.*

| | |
|---|---|
| Carbon dioxide absorbed from aliquot of outgoing air | Set No. 1 = 4.43 grams.<br>Set No. 2 = 4.43 grams. |
| Volume of aliquot of outgoing air | = 47.79 cu. ft. |
| $CO_2$ of aliquot from ingoing air | = 0.4779 × 1.48 = 0.71 gram. |
| $CO_2$ of aliquot produced in chamber | = 4.43 − 0.71 = 3.72 grams. |
| $CO_2$ produced in total outgoing air | $=\frac{3.72}{2.54^{**}}\times 100 = 146.5$ grams. |
| $CO_2$ produced by squad | = 146.5 + 3.1 = 149.6 grams. |

* After Nov. 11, 1917, it was assumed that each 0.001 per cent change in the residual corresponded to 0.8 gram of $CO_2$ and calculations were no longer made.

** 2.54 equals the percentage of the total outgoing air that actually passed through one set of the absorption system, *i. e.*, the factor for the 60 mm. disk.

TABLE 5.—*Summary of carbon-dioxide measurements with the group respiration chamber on night of Oct. 6-7, 1917.—Squad B.*

| Time of end of period. | Residual carbon dioxide in chamber by analysis. | (*a*) Change in residual content of carbon dioxide. | Analysis of aliquot. | | | | (*f*) Carbon dioxide produced by squad. $\left(e\times\frac{100}{2.54}\right)\pm a$ [1] | (*g*) Carbon dioxide produced by squad per hour. |
|---|---|---|---|---|---|---|---|---|
| | | | (*b*) Carbon dioxide from ingoing air. | Carbon dioxide absorbed from outgoing air. (*c*) Set No. 1 | Carbon dioxide absorbed from outgoing air. (*d*) Set No. 2 | (*e*) Carbon dioxide corrected for amount from ingoing air. $\left(\frac{c+d}{2}-b\right)$ | | |
| | *per cent.* | *grams.* | *grams.* | *grams.* | *grams.* | *grams.* | *grams.* | *grams.* |
| $12^h02^m$ a.m.. | 0.193 | ....... | ....... | ....... | ....... | ....... | ....... | ....... |
| 12 32 a.m.. | .191 | −1.7 | 0.70 | 4.37 | 4.38 | 3.68 | 143.2 | 286.4 |
| 1 02 a.m.. | .195 | +3.1 | .71 | 4.43 | 4.43 | 3.72 | 149.6 | 299.2 |
| 1 32 a.m.. | .193 | −1.8 | .71 | 4.51 | 4.48 | 3.79 | 147.4 | 294.8[2] |
| 2 02 a.m.. | .192 | −0.9 | .71 | 4.49 | 4.40 | 3.74 | 146.3 | 292.6[2] |
| 3 02 a.m.. | .191 | −0.9 | 1.42 | 8.80 | 8.79 | 7.38 | 289.7 | 289.7[2] |
| 4 06 a.m.. | .199 | +6.5 | 1.51 | 9.39 | 9.35 | 7.86 | 316.0 | 296.3 |
| 5 06 a.m.. | .197 | −1.4 | 1.41 | 9.04 | 9.00 | 7.61 | 298.2 | 298.2 |
| 6 06 a.m.. | .201 | +3.2 | 1.42 | 9.31 | 9.19 | 7.83 | 311.5 | 311.5 |

[1] 2.54 equals percentage of total outgoing air actually passing through one set of the absorption system.
[2] Periods from $1^h.02^m$ to $3^h.02^m$ a. m. selected as minimum periods. The average of these is 292 gms. $CO_2$ per hour. Total body-surface of squad equals 21.8 square meters. Assuming 3.025 calories as heat equivalent per gram of $CO_2$ at a respiratory quotient 0.81, the heat per square meter would be found by the following calculation:

$292\times3.025\div21.8=40.5$ calories per square meter per hour.

### ARRANGEMENTS FOR SLEEPING.

Night experiments alone were made in our use of this apparatus in the diet research. Twelve beds were provided in 3 sections of 4 beds each, as shown in figure 5, page 92. Good springs with suitable bedding made comfortable sleeping quarters. Glass jars for night urine were hung in wire frames at the foot of each bed.

## TECHNIQUE FOR DETERMINING EFFECT OF MUSCULAR WORK.

The men in Squads A and B were all engaged in various forms of muscular activity, ranging from the severe exercise of leading gymnasium classes for several hours a day to that of the activity necessary for moving about the campus from building to building. Even our most inactive man showed a considerable amount of muscular activity according to his pedometer and physical activity records. It was important, therefore, to determine the effect of the reduced diet on muscular activity and the physiological phenomena accompanying it.

### MEASUREMENT OF WORK OF BICYCLE RIDING.

For this purpose we fortunately obtained the cooperation of Professor A. G. Johnson, of the faculty of the International Young Men's Christian Association College. As a part of an extended study upon the influence of muscular activity upon the heart rate, which had been

it difficult to keep the apparatus clean. On the other hand, when the skirt was once put in place in the oil seal *a* of the base, it was not necessary to disturb it except to get at the lower part of the mill for oiling or for attention to the motor.

FIG. 14.—The treadmill chamber.

The treadmill rests on the base *A*, which has an oil seal, *a*, into which the skirt *B* fits. The subject stepped over the side of the skirt on to the treadmill and the cover, *C*, was lowered into the water seal, *b*, of the skirt. The treadmill was driven by the motor *D*, controlled by resistances not shown in the figure. Fans *E* and *E'* stirred the air and a blower, *F*, forced the air past the psychrometer, *G*, through the drier *H*. From *H*, the pipe went through a partition, *I*, into an adjoining room where samples of air were drawn at *J* for analysis. The air returned to the chamber through *L*, which was removable at the water seals *K* and *K'*. *M*, the tension equaliser or spirometer connected to a reserve spirometer *M'*. $N_1$, $N_2$, $N_3$, $N_4$, and $N_5$, resistance thermometers in series; a sixth one is not shown in the figure. *O*, window; *P*, electrical plug for temperature and pulse leads. *Q*, electrical plug for distance and step counters. *R*, electrical contact for recording revolutions of front pulley.

diameter. The belt is 435 cm. long and the portion on which the subject walks is supported by steel tube rollers with ball bearings.

The mill was driven by a 220-volt, D. C., $\frac{1}{3}$ H. P. motor (*D*) placed in front of the rear pulley, to which it was connected by a chain drive and reducing gears. The line to the motor entered the chamber between the base and skirt by being bent U-shape to conform to the trough of the base. Two variable resistances were inserted in the line at the observer's table for regulating the speed of the mill.

In order to have the experiments with the different subjects as comparable as possible, it was necessary to have the speed at which the subject was walking under constant observation and control. In previous experimenting a measure of the speed of the treadmill was obtained by means of a mechanical counter which recorded the revolutions of the front pulley of the treadmill. As the treadmill in this research was inclosed in a chamber, it became necessary by an electrical device to transmit these revolutions to a counter which could be under constant observation. This was done by attaching to the periphery of the front pulley a brass segment which made a wipe contact with a laminated brass finger fastened to the frame of the mill. With each revolution of the pulley an electric contact was made which actuated a counter placed on the observer's table and known in the telephone trade as a "p. b. x. message register." (See fig. 15.) As a precaution two such contacts and counters were installed and connected by a double-throw switch. In practice, however, no difficulty was experienced and only one counter was used.

FIG. 15.—Electrical counter.

The message register is shown mounted in a specially designed support which places it conveniently for reading.

To test the speed of the mill the time required for 10 revolutions of the pulley as recorded by the counter was noted with a stop watch, and by reference to a previously prepared chart the speed was immediately known. After the proper rate was established, which rarely occupied over a minute, further observations were taken every 2 minutes, and any adjustment that seemed necessary was easily and quickly made by the adjustable resistance. As a rule very little adjusting had to be done after the first 2 minutes and the speed was very constant. With uniformity of speed there was naturally uniformity in the distance

traveled during the periods, but there was always the possibility that on account of poor contact the counter might fail to register or that an occasional chatter of the contact might cause an extra number to be recorded.

To guard against this possibility, advantage was taken of the construction of the message registers which allowed the connection of a second circuit. This second circuit was carried to a signal magnet and a Blix-Sandström kymograph. With each operation of the message register this separate circuit was also completed through the signal magnet. As the kymograph was uniform in its movement, any skip or extra count in the message register would at once be apparent in the spacing of the signal magnet tracings on the kymograph. The records show no such irregularities and the numbers read off the message registers are believed to be accurate for the revolutions of the pulley. The counter was read at the beginning and end of a period. From these records and from the circumference of the pulley and the length of the experimental period, computations could be made of the total distance traveled and the rate per minute.

Factors which have to be considered when comparing the metabolism of different individuals during horizontal walking include the weight moved and the distance traveled in unit time.

It has been shown[1] that the energy expended during horizontal walking when calculated on a basis of kilogram weight and meter distance increases very slightly with the rate of walking up to a point of approximately 80 to 85 meters per minute. This point has been termed the "speed of maximum efficiency." At this point there appears to be a break in the curve and any increase in speed is done at a relatively greater cost in energy expended. Brezina and Kolmer[2] have shown that within this optimum range of speed the metabolism per kilogram and meter distance is independent of the weight carried up to a load of 20 kg.

It was desirable, then, to maintain a rate of walking within this optimum limit and a rate of 70 meters per minute was selected. This is a fair rate of walking and does not in 20 to 25 minutes introduce the element of fatigue. This rate was also convenient because the amount of carbon dioxide eliminated during the time available for the experiment, judging from other data, would in all probability not exceed 1 per cent of the chamber volume. The capacity of the Haldane gas-analysis apparatus used for the carbon-dioxide determinations was 1 per cent, as previously stated, and it was desired to use this small apparatus rather than other larger and more complicated forms. Furthermore it was desirable not to have so great a concentration of carbon dioxide

[1] Durig, Denkschrift. d. math.-natur. Kl. d. kaiserl. Akad. d. Wissenschaften, 1909, 86; also Benedict and Murschhauser, Carnegie Inst. Wash. Pub. No. 231, 1915, p. 85.

[2] Brezina and Kolmer, Biochem. Zeitschr., 1912, 38, p. 142.

STEPS
RESPIRATION
PULSE
TIME IN 1/5 AND 2 SECONDS

B

C

D

E

FIG. 16 —Photographic record of the pulse, respiration, and steps of *Bro* while he was walking in the treadmill chamber.

*A* and *B*, record for the standing-walking period. *A* and *B* together composed one continuous record which has been cut in two approximately equal lengths for illustration. *X*, point at which walking began. *C*, record at end of sixth minute. *D*, record at end of twenty-fourth minute. *E*, record for the walking-standing period. *Y*, point at which walking ceased.

of oxygen consumed from the chamber during this preliminary period would therefore be in the following ratio:

Per cent $CO_2$ found : per cent $O_2$ consumed :: R. Q. : 1

Deducting this calculated percentage of oxygen consumed from the percentage of oxygen in outdoor air would give the percentage of oxygen present in the chamber at the beginning of the period, subject to a correction for change in the volume of air in the chamber due to the fact that more oxygen has been consumed than carbon dioxide has been produced. Of the original air 100 volumes were composed as follows: $O_2$, 20.932;[1] $CO_2$, 0.031; $N_2$, 79.037; total, 100.000. The altered volume is composed of 79.037 parts of unchanged nitrogen plus an increased amount of carbon dioxide, and a decreased amount of oxygen, the total being less than 100. The true percentage of oxygen would therefore be larger in the proportion as the altered volume is to 100. From this corrected percentage and the volume of air in the chamber, the amount of oxygen present at the start is computed. The analysis of the air by the Sondén gas-analysis apparatus at the end of the experiment gave the combined percentage of oxygen and carbon dioxide, from which the percentage of oxygen was found by deducting the percentage of carbon dioxide as determined simultaneously on the two Haldane gas-analysis apparatus. The difference between the volume of oxygen present at the start and at the end, divided by the time, gave the oxygen consumed per minute. The data and calculations of a typical experiment are shown in tables 6 and 7.

TABLE 6.—*Records of metabolism experiment, with subject walking in treadmill chamber.*

Subject: *Gul.* Date, Feb. 3, 1918. Weight with clothes, 64 kg. Experiment began $7^h18^m$ a. m.

| Minutes of walking. | Reading of distance counter. | Reading of step counter. | Psychrometer. | | | Spirometer. | Temperature. | Barometer. | Carbon dioxide by Haldane. | | Oxygen and carbon dioxide by Sondén. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wet bulb. | Dry bulb. | Aqueous tension. | | | | 1 | 2 | |
| | | | °C. | °C. | mm. Hg. | mm. | °C. | mm. | p. ct. | p. ct. | p. ct. |
| Start | 5,945 | 9,521 | | | | | | | | | |
| 3 min. 30 sec. | | | 15.20 | 21.70 | 8.9 | | | | | | |
| 3 min. 45 sec. | | | | | | +75 | | | | | |
| 4 min. 00 sec. (start of period.) | 6,160 | 9,783 | | | | | 21.00 | 764.63 | 0.141 | 0.145 | |
| 13 min. 30 sec. | | | 15.30 | 20.95 | 9.5 | | | | | | |
| 13 min. 45 sec. | | | | | | +40 | | | | | |
| 14 min. 00 sec. | 6,682 | 10,380 | | | | | 20.63 | 764.63 | .422 | .439 | |
| 23 min. 30 sec. | | | 15.25 | 21.00 | 9.4 | | | | | | |
| 23 min. 45 sec. | | | | | | +116 | | | | | |
| 24 min. 00 sec. (end) | 7,207 | 11,006 | | | | | 20.56 | 764.48 | .704 | .708 | 20.872 |

[1] Benedict, Carnegie Inst. Wash. Pub. No. 166, 1912, p. 114.

TABLE 7.—*Calculation of metabolism experiment with Gul walking in treadmill chamber, Feb. 3, 1918.*

CALCULATION OF CARBON DIOXIDE PRODUCED.

(*a*) *Carbon dioxide present at start of period:*

| | | |
|---|---|---|
| | | Liters. |
| Apparent volume of chamber | | 2,419 |
| Correction for spirometer, 75 mm. ×21.5 c.c. | | 1.61 |
| | | 2,420.61 |
| Volume of subject | | 64.00 |
| Total volume | | 2,356.61 |
| Log. volume, 2,356.61 | =3.37229 | |
| " temperature 21.0 reduced to 0° C. | 9.96776–10 | |
| " barometer, corr.[1] 755.73 reduced to 760 mm. | 9.99756–10 | |
| " corr. volume | 3.33761 = | 2,175.8 liters. |
| " per cent $CO_2$ at start 0.143 | 7.15534–10 | |
| " $CO_2$ at start | 0.49295 = | 3.11 liters. |

(*b*) *Carbon dioxide present at end of period:*

| | | |
|---|---|---|
| | | Liters. |
| Apparent volume of chamber | | 2,419 |
| Correction for spirometer, 116 mm. ×21.5 | | 2.49 |
| | | 2,421.49 |
| Volume of subject | | 64.00 |
| Total volume | | 2,357.49 |
| Log. volume, 2,357.49 | =3.37245 | |
| " temperature 20.56 reduced to 0° C. | 9.96841–10 | |
| " barometer, corr.[1] 755.08 reduced to 760 mm. | 9.99718–10 | |
| " corr. volume | 3.33804 = | 2,177.9 liters. |
| " per cent $CO_2$, 0.706 | 7.84880–10 | |
| " $CO_2$ at end | 1.18684 = | 15.38 liters. |

| | |
|---|---|
| | Liters. |
| Vol. $CO_2$ at end | 15.38 |
| Vol. $CO_2$ at start | 3.11 |
| Vol. $CO_2$ produced | 12.27 |

Duration of period, 20 minutes. $CO_2$ produced per minute, 614 c.c.

CALCULATION OF OXYGEN CONSUMED.

(*a*) *Oxygen present at start of period:*

| | |
|---|---|
| Total per cent $CO_2$ in chamber at start | 0.143 |
| Assumed per cent $CO_2$ in original (outdoor) air in chamber | .030 |
| Per cent $CO_2$ produced at expense of the oxygen originally present in chamber | .113 |

$$\text{Per cent oxygen deficit} = \frac{\text{per cent } CO_2 \text{ produced}}{\text{R. Q. (assumed)}} = \frac{0.113}{0.81} = 0.140$$

| | |
|---|---|
| Per cent of $O_2$ in outdoor $CO_2$-containing air | [2]20.932 |
| Per cent of $O_2$ deficit in chamber air | .140 |
| Apparent per cent of $O_2$ in chamber air | 20.792 |

100 volumes of the air originally in the chamber, assumed to be of outdoor composition, would consist of 20.932 volumes $O_2$; 0.031 volume $CO_2$; and 79.037 volumes $N_2$; total, 100.000 volumes; but since there has been a diminution in the volume in the chamber due to the fact that more

[1] Observed barometer minus corrections for barometer temperature (brass scale) and aqueous tension.

[2] The oxygen in the air on a $CO_2$-free basis = 20.938 per cent; carbon dioxide = 0.031 per cent. (Benedict, Carnegie Inst. Wash. Pub. No. 166, 1912, p. 114.)

oxygen has been consumed than carbon dioxide has been formed, and since the volume of nitrogen is unchanged, it is evident that at the start of the period these 100 volumes are altered to the following: $N_2$ (unchanged), 79.037 volumes; $CO_2$ (by analysis), 0.143 volume; $O_2$ (by computation above), 20.792 volumes; total, 99.972 volumes, of which the percentage of oxygen would be

$$\frac{20.792}{99.972}\times 100 = 20.798$$

The correct percentage of oxygen at the start is therefore 20.798.

Volume of chamber at 0°, 760 mm. at start was 2,175.8 liters

| | |
|---|---|
| Log. volume of chamber at start of period 2,175.8..... | =3.33761 |
| " per cent $O_2$, 20.798.......................... | 9.31801–10 |
| " oxygen present at start........................ | 2.65562 =452.50 liters. |

(b) *Oxygen present at end of period:*

| | |
|---|---|
| By analysis with Sondén apparatus, per cent $O_2+CO_2$........... | =20.872 |
| By analysis with Haldane apparatus, per cent $CO_2$.............. | .706 |
| Per cent oxygen present at end of period................ | 20.166 |

| | |
|---|---|
| Log. volume of chamber 0°, 760 mm., at end of period, 2,177.9.................................. | =3.33804 |
| Log. per cent oxygen at end 20.166............ | 9.30462–10 |
| Log. volume oxygen at end of period.......... | 2.64266 =439.20 liters. |

| | Liters. |
|---|---|
| Oxygen present at start of period............................ | 452.50 |
| Oxygen present at end of period.............................. | 439.20 |
| Oxygen consumed...................................... | 13.30 |

Duration, 20 minutes.
Oxygen consumed per minute, 665 c.c.
Respiratory quotient, $\frac{CO_2}{O_2}=\frac{614}{665}=0.92$.
1,000 c.c. $CO_2$ at respiratory quotient of 0.92 =5.378 cals.;[1] *e. g.*, 614 c.c. =3.30 cals.

## PSYCHOLOGICAL PROGRAM AND TECHNIQUE.

The measurements of the neuro-muscular processes and the general mental condition of the men in Squads A and B were made at the Nutrition Laboratory when the men were in Boston, Saturday evenings and Sunday mornings. This arrangement of bringing the squads to Boston was a particularly advantageous one for the psychological phase of this research, as it made possible the securing of a maximum amount of data in the time at our disposal, with the least interference with the college duties of the subjects. Moreover, by doing this part of the work at the Nutrition Laboratory conditions were obtained which were more suitable and uniform throughout the experimentation than they would probably have been elsewhere. The students were away from their usual college environment, with its numerous interests and distractions. The college work for the week was completed. Since the men were all present and had no other duties or engagements than to serve as subjects in the psychological and other measurements, it was unnecessary to make individual appointments for an experimental session, a condition which unavoidably gives rise

[1] Benedict and Talbot, Carnegie Inst. Wash. Pub. No. 201, 1914, p. 29.

been worked out by Seashore, and was used in the present case.[1] Suitable wooden resonators were provided. The tuning-forks were all originally A435 vd. in pitch.[2]

The pitch differences were produced by filing between the prongs, hence all of the steps were lower than the standard, *i. e.*, the one fork which had not been filed and which was A435 vd. The pitch intervals between the standard and the other nine forks were 1, 2, 3, 5, 8, 12, 17, 23, and 30 double vibrations (*vd.*), respectively. The experimenter who sounded the forks was completely out of view of the subjects, and the usual precautions were taken concerning noises and such things as could serve as secondary criteria. Care was also taken to make the intensity of the tones equal and of similar duration. A chance order for the presentation of the tones was worked out previous to the tests and followed. Preliminary trials were given and explanations made to arouse interest in pitch discrimination. By numerous trials it was explained to all the subjects that the judgment was to be made in reference to the last of a pair of tones, *i. e.*, he was to judge if the latter of any two tones was higher or lower than the former of the pair. A blank, ruled in centimeter squares, was provided, upon which these judgments could be recorded conveniently, the columns being lettered across the top and numbered down the side at the left. The upper left-hand corner of this blank is shown about full size in figure 21. The judgment for the first pair of tones is recorded in square A–1. This is given in the illustration as *H*, meaning that the second tone was judged higher than the first of the pair. The judgment for the second pair of tones is recorded in square B–1. In figure 21 it is given as *L*, meaning that the second tone was judged to be lower than the first. The particular square in which the judgment was to be recorded was called out in the first experiment and at the first of each experiment just before the pair of tones was given, so that the subject might have no doubt as to where to write his judgment. He was required to make a judgment of either higher or lower, that is, to fill in the appropriate square with either *H* or *L*, according as it sounded to him. There were no judgments of equality.

At the first session with each squad all the pairs of forks were used. This would give 9 pairs of tones for discrimination purposes. It was then discovered that in the case of both squads the pairs of tones, S–30, S–23, S–17, and S–12, were quite uniformly judged correctly. Therefore, it was necessary to use only the remaining pairs in succeeding sessions, that is, S–8, S–5, S–3, S–2, and S–1, or 5 pairs of tones. Really, the pair S–8 might also have been omitted, as the subjects were almost always correct with this judgment. However, some easy judgment is

[1]Seashore, Report of the Committee of the American Psychological Association on the Standardizing of Procedure in Experimental Tests, Psychological Monograph, 1910, **13**, p. 21.

[2] The tuning-forks were those listed as No. 1730 in the catalogue of C. H. Stoelting Co., Chicago.

grip; continuous discrimination in finding serial numbers; efficiency in traversing the maze; and the clerical tasks). In these tests two men could work in the same room at the same time without disturbing each other. The subjects were located at two well-lighted tables placed some distance apart and not facing each other. The assistant, Mr. J. I. Waldron, whose careful service we were fortunately able to secure, occupied a position between them. The working conditions were made satisfactory to the men. One subject filled out the clerical test blank while the other completed tests Nos. 11 and 16. The time required for each subject to do his particular task was recorded by the assistant in seconds and fractions on a suitable form. The men then exchanged position and tasks. The strength of grip was usually taken after the other tests in room A were completed, and frequently one subject looked on while another subject was being tested. Each subject made a pulse count on himself when he had completed the clerical blank.

Room B contained measurements Nos. 8, 10, and 15 (patellar reflex, word reactions, and finger movements). The general set-up for these three measurements is shown in figure 31, p. 160. They formed a convenient group, since they all relied on the Blix-Sandström kymograph for chronographic record. The experimenter tested the subjects individually. The word reactions were always given as the first test, this being followed by the three finger-movement records. Between the finger-movement records there was an interval of one minute. In the first interval the subject was asked for any observations concerning his general condition. In the second interval, or that between the second and third finger-movement records, a pulse count was taken by the experimenter at the wrist. Following the last finger-movement record, the subject changed chairs and reclined in a steamer chair for the patellar reflex measurement, following which a second pulse count was made by the experimenter. The time required to complete the tests in room B was from 17 to 20 minutes. The subject was then sent to room A or C, if he had not previously had the measurements in these places.

In room C, which is the main psychological laboratory, measurements Nos. 12 and 13 were given. The threshold for electric shock was always first and that for visual efficiency came second. There was a shift of position and a slight intermission between the measurements and 8 to 10 minutes devoted to each one. There were, of course, individual differences, and it was not possible to take exactly the same amount of data on each man. When the measurements had been completed or the time interval allowed had elapsed, the subject was sent to another room or upstairs.[1] The two measurements were taken by Mr.

[1] Some latitude in time for testing a particular man was naturally allowed, but in general, a serious effort was made to maintain a schedule, as it was only on this basis that it was possible to test 12 men in such a variety of ways within a period of 3 to 3½ hours.

Edward S. Mills, whose thorough understanding of the apparatus and intelligent cooperation as assistant in psychological investigations during the last few years insured care in execution.

The measurements made by the group method and the three series of individual measurements just outlined made up the evening psychological session. No effort was made to have the men serve as subjects in identical order each evening, nor was it expedient to give tests in the same order to the individual subjects each evening.

In addition to the measurements made in the evening, a number of tests were made in the morning after the subjects had spent the night in the group respiration chamber. At these morning sessions, also, the subjects were taken in an order which was most convenient to themselves. The distinctive measurements for the morning session were: Nos. 7, 9, and 14, that is, changes in pulse rate with exertion, reaction time of the eye, and speed of eye movement. These were all in room C, and required the attention of an experimenter and an assistant, Mr. Mills. Finger-movement records, pulse counts, and strength of grip records were taken by a second assistant, Mr. Waldron, in room B. The subjects were called, dressed, ate their breakfast, and came to be tested in groups of 3. It required about 20 to 25 minutes for each group. A particular subject began with room B or C, as was convenient for the experimenter. One subject served at a time in room B, two were tested simultaneously in room C—one for the pulse measurements and the other for the eye measurements. The first subjects were ready at $6^h30^m$ a. m. When they had completed the measurements at about 7 a. m., they left the Laboratory not to return until the next session, usually two weeks later. The last subjects tested were ready to leave the Laboratory about $8^h30^m$ a. m.

The individual measurements as distributed between the evening and the morning sessions and in the three rooms are therefore as follows:

Evening:
- Room A.
  - 6. Strength of grip.
  - 11. Continuous discrimination and reaction in finding serial numbers.
  - 16. Efficiency in traversing a right-angle maze.
  - 17. Efficiency in performing certain clerical tasks.
- Room B.
  - 8. Latency, amplitude, and refractory period of patellar reflex.
  - 10. Reaction time for speaking 4-letter words.
  - 15. Speed of the finger movements.
- Room C.
  - 12. Sensory threshold for visual efficiency.
  - 13. Sensory threshold for electric shock.

Morning:
- Room C.
  - 7. Changes in pulse-rate occasioned by short periods of exertion.
  - 9. Reaction time for turning the eye to a new point of regard.
  - 14. Speed of the eye movements.
- Room B.
  - 15. Speed of the finger movements.
  - 6. Strength of grip.

ing and the standard weights. The average error, particularly in that range which was commonly employed, which is from 35 to 70 kg., is usually less than ±0.2 kg. with the higher temperature, which was more nearly the condition used under actual experimentation, as the subjects desired to have the rooms in which they worked quite warm.

It was seen that no such discrepancies or errors between standard weights and dynamometer readings were found in the case of this instrument as those recorded by Kohs, and therefore our readings are given without correction. With the exception of three occasions, the readings were always made by the same individual. These times were: the evening of December 19, Squad A; morning of February 3, after the walking experiment, Squad A; and the records which were taken in Springfield on May 21 and 22.

TABLE 8.—*Calibration to check the accuracy of the hand dynamometer used in this research.*

| | 25° C. | | 13.5° C. | | | 25° C. | | 13.5° C. | |
|---|---|---|---|---|---|---|---|---|---|
| Standard weights in kg. | Average reading of 5 trials. | Average error between standard weight and reading. | Average reading of 5 trials. | Average error between standard weight and reading. | Standard weights in kg. | Average reading of 5 trials. | Average error between standard weight and reading. | Average reading of 5 trials. | Average error between standard weight and reading. |
| 5 | 5.00 | ±0.00 | ........ | ........ | 45 | 44.84 | −0.16 | ........ | ........ |
| 10 | 9.94 | −0.06 | ........ | ........ | 50 | 49.90 | −0.10 | 49.54 | −0.46 |
| 15 | 15.30 | +0.30 | ........ | ........ | 55 | 55.14 | +0.14 | ........ | ........ |
| 20 | 20.36 | +0.36 | 20.12 | +0.12 | 60 | 60.06 | +0.06 | 59.34 | −0.66 |
| 25 | 25.32 | +0.32 | ........ | ........ | 65 | ........ | ........ | ........ | ........ |
| 30 | 30.20 | +0.20 | 30.02 | +0.02 | 70 | 70.32 | +0.32 | 69.62 | −0.38 |
| 35 | 34.94 | −0.06 | ........ | ........ | | | | | |
| 40 | 40.20 | +0.20 | 39.98 | −0.02 | Error. | ........ | +0.117 | ........ | −0.23 |

### (7) CHANGES IN PULSE-RATE OCCASIONED BY SHORT PERIODS OF EXERTION.

This was one of the morning measurements. A brief review of literature pertaining to pulse records of this sort and a description of technique previously used has been given in another publication by one of us under the convenient name of "tetanus pulse."[1] Formerly the changes in pulse-rate were produced by the subject's clenching his fists and making the muscles of arms, legs, and trunk rigid for a given period, after which he relaxed in a steamer chair as he had been previous to the exertion. From the standpoint of quick transitions from rest to exertion, and from exertion to rest, no routine can be better, but, as pointed out in the previous publication, much depends upon the subject for the amount of exertion actually put forth and in sustaining it with some uniformity during the period.

[1] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 92.

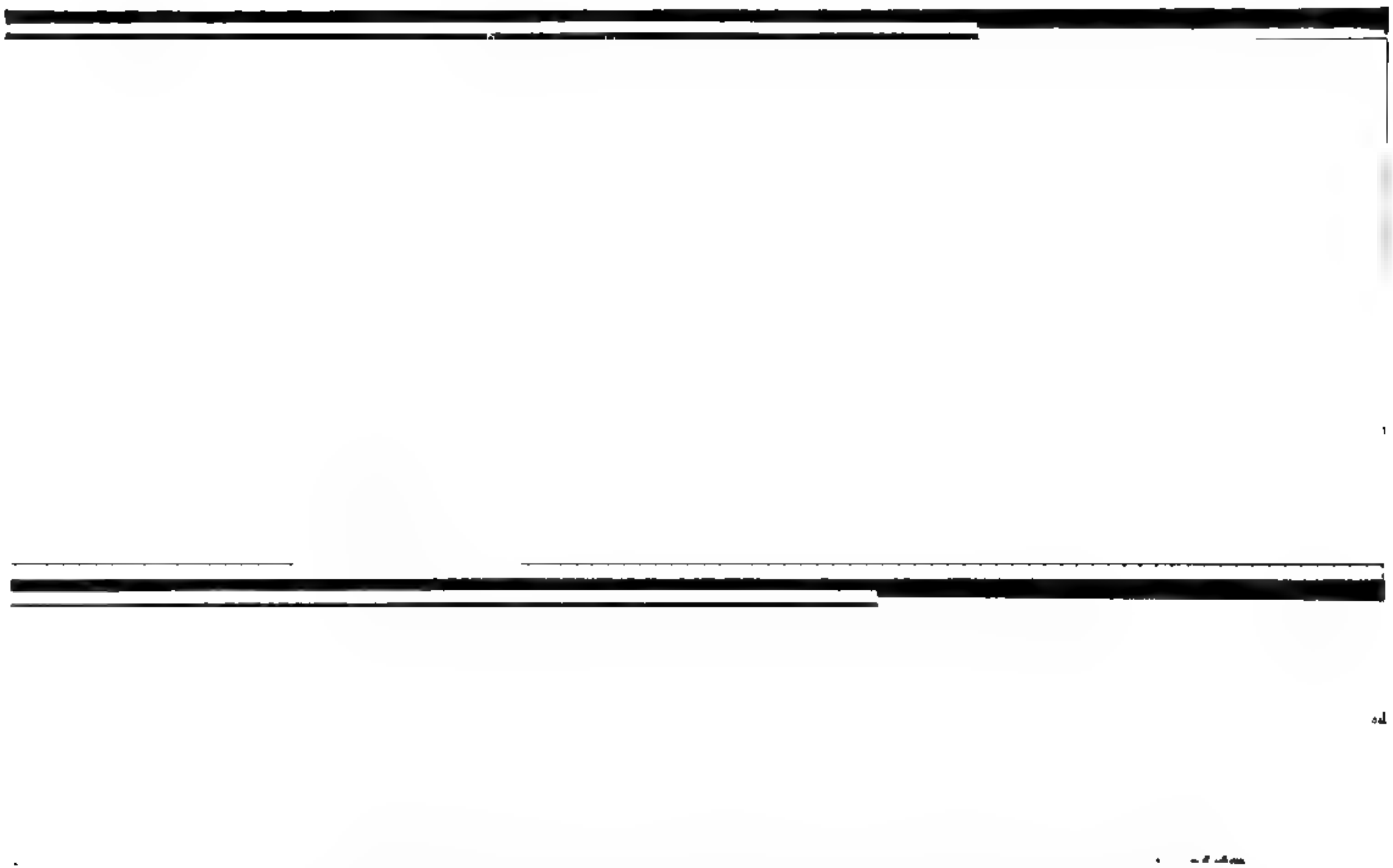

Fig. 24.—Sample pulse records showing changes in the pulse-rate occasioned by short periods of exertion.

*A* and *A'* are parts of the same continuous record, which has been cut for purposes of illustration. From the left-hand end of *A* to the point *U*, the subject was resting quietly in the steamer chair, at *U* (up) the weight was lifted and this muscle tension was continued to *D* (down, shown in *A'*), when the subject let himself down into the chair and was relaxed until the end of *A'*. The same description would apply to *B* and *B'* or to *C* and *C'*. The pulse-cycle length is measured from *R* to *R*, and the time is in one-fifth second. The small irregular vibrations in the pulse line show the period of activity, which obviously began before *U* and continued slightly beyond *D*. In the post-activity section of *B'*, the pulse-cycle length returns to normal rather slowly as contrasted with the changes shown in the similar section of *C'*.

the edge of the metal strip and all were secured to the felt at the back. A regular 4-foot telephone cable, with wires designated, which ends in the usual switchboard plug fitting into the ordinary receptacle was employed for purposes of connection. This offers very quick connection and good contact. The gauze on the face of the pad was moistened in warm saturated sodium chloride solution. Pads *R* and *L* were placed in contact with the skin on the right and left sides of the subject; *G* was placed between them and somewhat lower on the abdomen. Two bands of elastic tape about the subject's chest held the pads in position. This tape did not have to be uncomfortably tight. Although unnecessary in these experiments, the pads could be worn a long time without annoyance, and they made good contact with the body for an indefinite time. The many thicknesses of cotton gauze provided against any scratching of the skin. *R* and *L* connected with the two terminals of the galvanometer string. *G* was connected to earth as a "ground." This method was found to be more satisfactory than to earth the frame and coils of the string galvanometer. With these electrodes it was nearly always possible to get satisfactory pulse records while the subject was engaged in the vigorous activity called for by the test.[1] These same electrodes were used in recording the pulse when the subject walked on the treadmill (see p. 129). Several sets of electrodes facilitated the experimenting.[2]

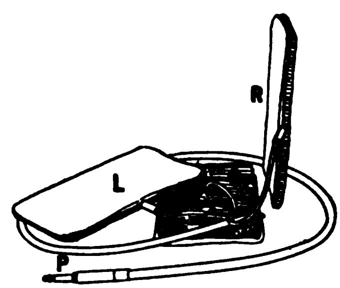


FIG. 26.—The body electrodes used in recording electrocardiograms during physical activity.

The pads were 11 cm. wide and 20 cm. long; each pad was made of 8 layers of cloth, a sheet of thin metal, and a piece of felt for backing. In use, the cloth is moistened in salt solution. *R* and *L* were applied directly to the skin on the right and left sides of the subject and connected to the string galvanometer. *G* was applied just above the navel and connected to ground; *P*, regular 3-lead telephone plug.

The electrocardiographic apparatus had been arranged in general to facilitate the taking of such records. In the nature of the case, it is most convenient to have the subject near the apparatus, but the apparatus should not be such as to annoy or distract the man. The electric motor which operated the camera was placed in an adjoining room and could run indefinitely with no disturbance. The illumination was from an automatic arc lamp. The

[1] A prominent exception to this statement is found in *Gul* of Squad A. It could never be determined with assurance whether the action currents from muscles of limbs and trunks were in his case exceedingly strong or whether this subject carried about in his body an immense static charge. However, almost every time he was tested he put the galvanometer string out of order. His case was exceptional. Nothing similar was encountered in a group of 65 young men tested previous to this research. No criticism is made of him, for he followed instructions as well as any subject could.

[2] These electrodes might not be the most satisfactory form for long periods of walking or other physical exertion, as they could shift into position of contact, one with the other, unless special arrangement was made to avoid this.

the left, the fall (*1*) in the line is caused by the stimulation of the tendon; the second drop (*2*) is from the reflex thickening of the muscle. The distance from the beginning of *1* to the beginning of *2* is the latency for the reflex, which is measured in thousandths of a second (the kymograph speed was 100 mm. per second). The amplitude is the vertical



FIG. 29.—A portion of a sample record for the evening measurements in room B.

The curves above the cross, which is in the left of the figure, are from the patellar reflex and show a gradual shortening of the interval between stimuli until the reflex for the second stimulus is absent. The wavy and more or less irregular lines in the lower portion of the figure are from the finger movements. The black dots were caused by the jump sparks and indicate the 2-second intervals. The horizontal broken lines in the lower section are the word-reaction records.

oil through the by-pass cylinders, *B*.[1]) The up and down movements of the plate-holder were made to open and close a shutter, *S*, by means of the cords *1* and *2*. When the plate-holder was drawn up by hand, just before it reached its highest position, and when the ground glass, *G*, came opposite the shutter *S*, string *1* became taut and opened the shutter. This remained open until the fall of the plate was complete. String *2* then became taut and closed the shutter. Thus the plate was protected from fogging, except during the actual moments when reactions were being recorded or the camera was being focused.

A sliding contact was arranged at *C* (figure 30) in the camera. This completed a circuit for the small solenoid *S* (see figures 34 and 35). This by its action caused the light to be turned on the eye of the subject at the same instant that the stimulus should appear. After the plate had completed half its fall the current was cut off from the solenoid by the breaking of the contact. This contact, *C*, was composed of two slots in a hard-rubber block, the slots running slightly diagonal to the perpendicular movement of the plate. A small wire brush placed at the upper right-hand corner of the plate-holder moved in these slots. When the plate was at the top this brush was in such a position that it slid down the left-hand slot, which was lined with copper. It thus completed the circuit and actuated the solenoid mentioned. In its downward course the brush was gradually drawn to the left. When the plate had passed half its fall and the brush left its path, it swung back in such a position that when the plate-holder was raised it traveled up the path at the right, which, being composed of hard rubber, did not complete the circuit through the solenoid. In this way the stimulus and exposure of the eye did not have to be separately operated, but were automatically timed in relation to the fall of the plate.

The strings which hang from the end of the table (see *X* in figure 30) connect with the stimulus device. As the operator sits at this end of the table behind the camera they are in easy position for him to use.[2] The easily controlled and silent action of the stimulus apparatus, the accurate means for shifting the position of the camera, the automatic action of the shutter to avoid the fogging of the plate, and the automatic timing of the stimulus in relation to the fall of the plate, all contributed to make possible the taking of reactions with a minimum loss of time. If it is not the first time the subject has served in the experiment, 6 to 8 minutes is ample for the taking of two plates, that is, a total of 25 to 35 reactions. These modifications also help to make possible the control of the apparatus from one position and by one person.

The adjustable head-rest which made possible the placing of the subject in position quickly, and later his placing himself in position, is

[1] See description in Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 80.

[2] In figure 50, p. 185, the schematic ground plan of the apparatus for eye reactions and eye movements at the subject's end is shown. *C* in this figure represents the stimulus apparatus and the cords to operate the same which extend to the other end of the table, hanging there in convenient position for the experimenter.

shown schematically in figure 32. The forehead of the subject was placed against the curved wooden support, *S*. A wooden peg, *T*, was taken between the teeth. The blind, *B*, was down in front of the eye or raised up out of position. In the test for the eye reaction it was always raised out of view, as the subject looked at the stimulus with both eyes. The lens of the camera was at position *A* in the figure. The support *S* may be raised and lowered as indicated, but usually it was not necessary to make any change here. The adjustment was commonly with the two rack-and-pinion devices, operated by knurled heads, *K*, and with the movable tooth-rest. The clamp *W* was first released by turning the wing-nut; then the whole frame of the head-rest was shifted laterally or vertically as the case required. When the position was found, the clamp *W* was tightened; the support for the head was then rigid. The whole frame could be moved far enough to the right so as to use the left eye for photographing if desired. The changing of the wooden pegs and the cleaning of the nickel-plated support are easily done. The right-hand bearing of the lower rack-and-pinion device is fitted with a clamp so that the head-rest will not have a tendency to drop down without the observer's knowledge.

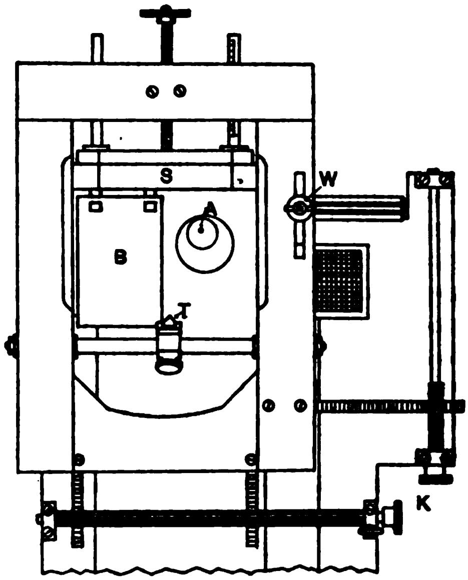


FIG. 32.—Diagram of the adjustable head-rest.

*S*, forehead support; *T*, tooth rest; *B*, opaque blind for left eye; *K*, knurled heads controlling the rack and pinion devices; *W*, wing nut clamp for fixing the head-rest in any desired position; *A*, position of lens or artificial pupil.

The general arrangement of the apparatus from the subject's end may be seen in figure 35. The head-rest is shown in profile. A white line has been drawn in the picture to show the general course of the beam of light which is used to photograph the movements of the eye. The beam is of soft blue light, and when the subject is following instructions can only be seen in indirect vision. As used in the experiment it is not tiresome to the eye, but has sufficient actinic power for the photographic recording. In actual operation a small shield (see the black perpendicular line to the right of *A* in figure 35) obstructs the path of the photographing light so that it does not fall on the subject's eye until the exact moment when the stimulus light appears. The stimulus light appears in a position to the left of the subject's field of view, in the location indicated by *L* in figure 35. The area over which these stim-

ulus lights may appear is about 25 cm. square. This area forms one side of the lamp-house, *H*, which contains four 60-watt Mazda lamps. The lamps were arranged upon a cluster plug; the inside of the house was white, ground glass being used to diffuse the light. There were 28 stimulus units arranged in the door of the box which faces the subject. A section of this part of the stimulus apparatus is shown diagrammatically in figure 33 from within the box. *W* is a three-ply wooden door. On the outside of this, that is, near the subject, is a milk glass, *G*, and over this a metal plate, painted flat black and containing holes 2 mm. in diameter, through which the light may pass to the subject's eyes. Twenty-eight small shutter devices, like that shown at *S* in figure 33, were arranged. When opened by the cords *C* (which extended to the operator's end of the table, see fig. 30) they each exposed a round hole in the door, 1 cm. in diameter. In this way the light was allowed to fall on the milk glass and a certain portion of it went through the opening in the plate to the subject's eye. The shutters were all fitted with black velvet, thus making them light-tight when not operated. The four 60-watt Mazda lamps were in parallel, as shown at *L* in figure 34, and constantly in series with the resistance *R*. Thus, when contact was made at the mercury switch, *M* (figs. 34 and 35) the resistance *R* was swiftly short-circuited and the lamp filaments came to full brilliancy in a very brief interval.[1]

FIG. 33.—Detail of the small shutters and windows in the eye-reaction stimulus apparatus.

*S*, shutter controlled by cord, *C*, for opening the 1 cm. holes, *H*, in the wooden door *W*; the light thus came to the milk glass, *G*, and a portion of it passed through the 2 mm. opening in the thin metal sheet, *T*, the exposed surface of which was painted flat black.

The circuit of the solenoid, *S* (figures 34 and 35) was completed by the sliding contact *C* (figures 30 and 34), as explained in connection with the modifications made in the falling-plate camera. From figure 35 it may be noted that when the solenoid acted, the part designated as *1* was shifted to the left in the picture. This caused the falling of the frame *2* resting on the top of *1*. This frame carried the shield *A*, which interrupted the beam of light until that moment when the falling of this frame turned the photographic

[1] In this report our interest is in comparative results. It may, however, be stated that 0.02 second for latency of apparatus should be deducted from the values as printed to reduce them to an absolute basis. This factor was determined from photographic records taken specifically to reveal the constants of the apparatus.

light on the eye of the subject and at the same instant completed the circuit in the mercury switch, *M*.

The sequence of events just preparatory to recording an eye reaction was therefore as follows:

(1) The operator grasped some one of the cords leading to the stimulus device and, by gently pulling, opened a window and held it open. The lamp filaments were glowing red in the box behind the milk glass, but did not give off enough light to make it possible for any subject to discover which window was open.

(2) The photographic plate was released. Very early in its fall it completed the circuit for the solenoid. The action of this quick and powerful magnet released the frame designated *2* in figure 35.

(3) The sudden downward movement of the frame and its parts caused the exposure of the eye to the soft blue photographic light, and at the same instant the completion of the short circuit which brought the stimulus light to full brilliancy in the opened window.

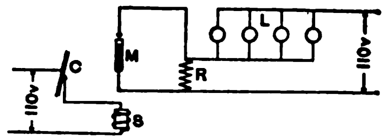


Fig. 34.—Wiring diagram for the eye-reaction stimulus apparatus.

*L*, four 60-watt Mazda lamps in parallel; *R*, resistance always in circuit; *M*, mercury switch for short-circuiting *R*; *C*, sliding contact; *S*, solenoid for operating *M*.

Two other cords shown as *C* in figure 35 were useful in manipulating the apparatus. One was connected with the shield which temporarily interrupted the beam of light from the subject's eye. This could be drawn down for a moment when focusing and finding position. The other was so arranged that, by pulling on it, the frame *2* could be raised into position after a reaction had been taken and thus made ready for another reaction. This lifting of *2* cut off the light from the subject's eye and broke the circuit to the lamps in the house, *H*. In the photograph made for figure 35, three of the shutters have been opened so as to expose the light, which can be seen at the points near *L* in the figure. In the center of the field at which the subject looked there was a white fixation mark which always re-

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Explanation of Figure 35.

*B*, black screen surrounding subject's field of view; *H*, lamp house of stimulus apparatus; *L*, general location of stimulus lights; *F*, a screen carrying a fixation mark and to be folded down over the plane *L* when eye movements are photographed; arrows indicate the path of beam of light; *S*, a solenoid which, when operated, moves support, *1*, to left, causing frame, *2*, to fall; *2* carries the shield, *A*, and a part of the mercury switch, *M*; thus, its fall lights the lamps in *H*, producing a stimulus at *L*, and exposes the eye to the recording light; *C*, two cords, one for lifting *2* again into position, the second for withdrawing *A* while the camera is focused.

Explanation of Figure 36.

Each line of dots is a reaction record. A black dash with one interspace represents 0.01 sec. Counting from the bottom (stimulus) the first definite bend in a line of dots indicates the moment of reaction, *e. g.*, in the extreme left hand record 20 dashes are counted between these points; the reaction time was therefore 0.20 sec. The records are from two subjects; those in the left hand plate show shorter and more regular reactions.

mained unchanged.[1] The stimulus openings were arranged on four axes passing through this fixation mark, that is, horizontal, vertical, and at angles of 45°. The points were 2 mm. in diameter and on any axis were arranged 3, 6, and 12 cm. from the central fixation mark. In the four corners of the viewed field there were points which were 15 cm. from the fixation mark. The field was 45 cm. from the subject's eye.

The stimulus device was perfectly satisfactory for our purpose, save that occasionally some one of the shutters would fail to close completely. In the measurements taken in this research and in many others made previously no secondary criteria can be discovered as coming from the stimulus apparatus. A slight sound due to friction can be heard when a string is pulled to open a shutter previous to giving the stimulus for reaction, but this sound is localized, as being behind the lamp house and under the table. In this investigation the inner ring of stimulus positions, that is, those which were only 3 cm. from the fixation point, were not used, nor were the positions vertically above and vertically below the fixation position. This limited the number of stimulus positions to 16, all of which were used with about equal frequency with any one subject.

Sample records of the eye reaction are reproduced full size in figure 36. The light which falls upon the subject's eye is interrupted by a timing vibrator and so causes the photographic record to appear as a row of short dashes. Each dash with one interspace is equal to 0.01 second. The records are to be read from the bottom upwards. When the line of dashes suddenly turns right or left it indicates that the eye of the subject has moved in the direction of the stimulus light. The number of dashes from the beginning of the record to the point where movement begins gives the reaction time. The records illustrated are from two subjects. Those shown in the right-hand plate are seen to be, in general, longer and more irregular than the others.

### (10) Reaction Time for Speaking 4-letter Words.

The apparatus for the word-reaction measurement comprised a kymograph with a circuit breaker (fig. 27, *C*, the movable contact), a Deprez signal magnet, an exposure apparatus, and voice key. The general arrangement of the apparatus is illustrated in figure 31. The Deprez signal marker is seen above and in contact with the kymograph.[2]

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[1] In the stimulus apparatus previously used, the fixation mark disappears at the instant when the true stimulus comes into view. This gives the eye the impression that the fixation mark has shifted position rather than that something new has appeared.

[2] Another signal magnet not distinguishable from the Deprez marker in figure 31 is used for control time on the kymograph. This marker comes in contact with the kymograph for a very short period every 2 seconds. This method of controlling the time was used by Dodge and has the unique advantage that while the time is on the record it is not conspicuous and does not complicate the other curves. See figure 28, page 157, for the wiring diagram, and figure 29, page 158, for sample record showing control time.

The exposure apparatus $E$ (see figure 31, page 160) when used is slipped into position at the end of the kymograph and clamped to the post $P$. The stimulus words were visible to the subject through the window $W$. The voice-key $V$ is connected with flexible cables and may be used in any convenient position. The voice-key is the one used by Dodge and Benedict, and described and figured by them in their publication.[1] The exposure apparatus was also the same as that described by Dodge and Benedict in their figure 30, which shows the construction of the back of the apparatus not visible to the subject.

One modification which greatly facilitated the taking of reactions with this exposure apparatus was in the clip which holds the card in position for exposure at the end of the movable arm. A holder was substituted which would contain a pack of 25 cards, each card having a stimulus word printed on it. Thus, following a reaction, it was only necessary to lift the arm of the exposure apparatus and withdraw the card bearing the word which had just been reacted to; the apparatus was then ready for the next reaction when the movement of the kymograph shaft broke the circuit and caused the second stimulus word to come into view in the window. Previously, when it was necessary to put in a card before each reaction, as well as withdraw the one which had just been reacted to, it was not possible to take reactions faster than one in every 10 seconds. This made the measurement somewhat tedious, or at least it appeared so with certain subjects.[2] With the pack arrangement of the stimulus cards it was easily possible to take reactions every 5 seconds, and had there been a convenient kymograph speed the time could have been still shorter without inconveniencing the subject or the experimenter.[3]

The position of the exposure device, with reference to the subject and to the other items of apparatus, is shown in figure 31. The subject sat in a position which would be at the extreme left in this figure. The voice-key $V$ was held in the right hand and the arm was supported on a convenient rest not shown in the picture. Thus the moving kymograph drum and other distracting features of the apparatus were hidden from the view of the subject, as the exposure apparatus occupied the greater part of his field of view. The area about the window, where the stimulus words appeared, was a light gray.[4]

[1] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 99, fig. 16. Photographic records for the latency of the voice-key as connected with different signal markers, and for the pronunciation of different words are given by them in their figs. 17 to 20.

[2] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 66.

[3] Reference should be made to fig. 28, p. 157, for the wiring diagram for the word-reaction apparatus.

[4] In the previous use of this apparatus (Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915; Miles, Carnegie Inst. Wash. Pub. No. 266, 1918) the exposure device was placed at the other end of the kymograph. (See Dodge and Benedict, p. 95, the lower right-hand corner of fig. 14.) The subject occupied the same position as in the present research, and thus had the moving kymograph in his field of view when he was reacting to the words presented by the exposure apparatus.

(12) Sensory Threshold for Visual Efficiency.

The general arrangement of the apparatus for the measurement of visual "acuity" is indicated by the schematic diagram in figure 39. The subject occupied a position at the left end of the apparatus while the operator was at the right, where he could manipulate the test object and record the readings, but be entirely hidden from the view of the subject. When the subject is in position against the head-rest *R* the artificial pupil *P* is in convenient position for the right eye. The line of vision is from *P* through a diaphragm opening, *D*, through the hood *H*, with its several screens *S* which reduce to a negligible quantity the reflected light from the four sides of the hood, to the test object *O*. In a suitable inclosure *LH* a lamp is arranged so that the light is reflected at *X* and thrown through the test-object window. The test object is manipulated by the micrometer adjustment *M*. The head-rest was the same as that used in connection with the eye-reaction test (see fig. 32, p. 162). *A* in figure 32 represents the artificial pupil and its mounting, shown as *P* in figure 39. The dark blind *B* in figure 32 was in front of the subject's left eye. The lens of the camera, which usually is directly in front of the right eye (see fig. 35) was withdrawn and in its place a telescoping tube 5 cm. in diameter and 28 cm. in length was put in position. The end of the tube near the subject carried a small projection which was suitable for adapting the apparatus to the contour of the subject's face. At the end of this projection the artificial pupil was located. The whole telescoping tube (*T* in fig. 39) could be moved easily, so

Fig. 38.—The movement pattern which should be followed by the hand in pointing out the numbers in order.

*S*, start of test; *E*, end.

that the artificial pupil was as close as convenient to the eye of the subject. The distance was usually not more than 1 cm. At the other end of the tube there was a diaphragm (see *D* in fig. 39). The round opening in this was 12 mm. in diameter. Its use and importance will become clear in later paragraphs.

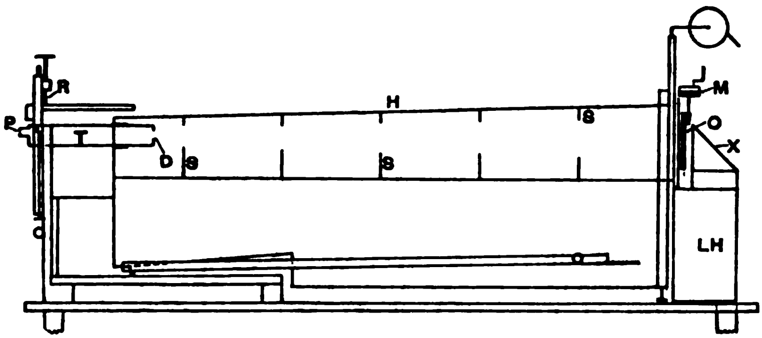


FIG. 39.—Arrangement of apparatus for the measurement of visual efficiency.

*LH*, lamp house; *X*, mirror to reflect light through the test object, *O*; *M*, micrometer for adjusting width of test bands in *O*; *H*, hood excluding extraneous light; *S*, velvet screens to reduce reflected light from walls of hood; *T*, telescoping member at one end of which is the diaphragm, *D*, for limiting the area of view; at the other end the artificial pupil, *P*, is placed near the subject's eye; *R*, head-rest shown in figure 32.

The artificial pupil was a round opening in a flat black surface and was 3 mm. in diameter. This size of artificial pupil was adopted as the result of a large series of observations which had been carried out previ-

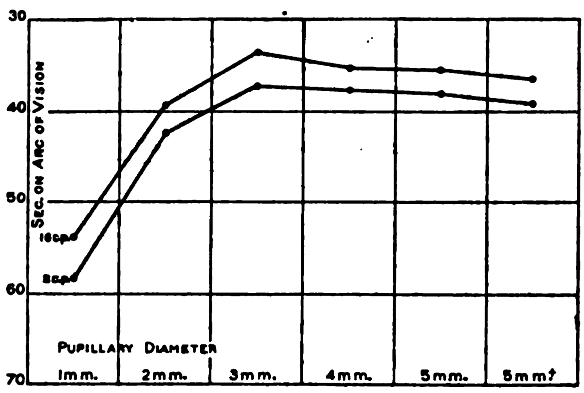


FIG. 40.—Visual efficiency with different diameters of artificial pupil.

The ordinate marked 5 mm.+ shows results when no artificial pupil was used.

ous to the present research. Data for this factor are shown in the curves of figure 40. These curves are based on about 1,200 threshold determinations on one subject, who served on different days, but under conditions which may be considered as uniform. Optimum vision is

found to be with an opening of 3 mm., which is much better than an opening of 2 mm., but not significantly better than one of 4 mm. This agrees thoroughly with the findings published by Cobb.[1]

The falling-plate camera, which, when in use, is at the right-hand end of the hood (see *H* in the diagram in fig. 39), is so hinged that it may be swung to the left and the visual-acuity object made to take its position at the end of the hood. This arrangement is evident in figure 41. Here the camera *C* has been swung partly out, but not far enough to allow *LH*, the lamp house, carrying the visual-acuity object, to come into position. The opening at the farther end of the hood may be seen as a bright spot between the camera and the lamp house.

The test object here used for determining the visual efficiency was one in which the width of a set of alternately dark and light bands could be continuously varied without changing in any way other factors in the stimulus field. The average brightness of the field is the same for all widths of lines.

The principle upon which this type of test object is built, which allows a continuous gradation in the width of the line without changing the total light flux of the field, has been described in detail by Behn,[2] Ives,[3] and Johnson.[4] It is unnecessary to repeat details here. The essential fact is this: If two glass plates are ruled with fine parallel lines, the width of line and interspace being made the same, and the lines are filled with an opaque substance, when these two plates are superimposed in such a position that their sets of lines are not quite parallel, coarse feather-edged bands alternately light and dark and of equal width will be seen distributed over the surface when light is transmitted through both glasses. If one plate is slowly rotated in reference to the other about an axis perpendicular to their surfaces, the width and total number of visible lines will gradually change. The lines are always uniformly distributed over the field of view (see figure 51, page 186). As the angle of rotation is increased, each visible band, both light and dark, decreases in width and new bands crowd into view from each side of the field. A suitable mounting to hold two such ruled gratings and to move them under measurable conditions slowly, and in opposite directions about an axis perpendicular to their surfaces was designed by Cobb.[5] This mounting of Cobb, improved in certain particulars, is described by Johnson, who gives working drawings.[6] The test object belonging to the Nutrition Laboratory was made for us at the Nela Research Laboratory of the National Lamp Works, Cleveland, Ohio, under the kind direction of Dr. H. M. Johnson, and in

[1] Cobb, Am. Journ. Physiol., 1915, **36**, p. 335. Data are given for three subjects.
[2] Behn, Ber. d. deutsch. physikal. Gesellsch., 1906, **4**, pp. 207 ff.
[3] Ives, Electrical World, 1910, **40**, p. 939.
[4] Johnson, Journ. Animal Behavior, 1914, **4**, p. 319.
[5] Cobb, Am. Journ. Physiol., 1911, **29**, pp. 76 ff.
[6] Johnson, Journ. Animal Behavior, 1914, **4**, p. 319.

corresponded to the position of the test object, it was reasonable proof that the subject had actually seen the lines and had not reacted to some false impression, which, with many untrained subjects, would quite naturally be the case, provided the subject knew in what axis the lines were going to appear. The test object window was round so that a shift in the axis would produce no observable difference in its shape or position. Experience has shown, however, that an experimental difficulty is encountered when the whole window and frame are exposed to the subject.

In figure 51 (see page 186), we reproduce a full-sized photograph of the window of the test object. The bottom and right-hand edges of the figure, as well as the lower right-hand portion, have been covered with a black paper mat; the other portion shows the circular boundary of the window. If the reader will hold this illustration at arm's length it will be seen that certain parts of the boundary for the light and dark lines have particular prominence, as, for example, positions 1 and 3, as contrasted with 2 and 4. This phenomenon can not be seen in the illustrations which have been shown by Ives,[1] who figures only square areas of such striæ as are under consideration. When looking at the test field, surrounded by a definite black circular frame, it is possible, after a little practice, to sense the presence of lines and to give their direction on the basis of this intersection phenomenon where the lines form acute angles with the dark border. It is also possible to do this with smaller lines than can be seen in the center of the field. When using the test object in only one axis, as has apparently been the custom at Nela Research Laboratory, where Ives, Cobb, Johnson, Luckiesh, and others have used this test object in a number of researches, it is doubtless possible with practised subjects to instruct them to give attention only to the center of the field, and judge when lines appear there.

For the purpose of our investigation and other investigations at the Nutrition Laboratory, it seemed highly desirable to eliminate this criterion for judgment. The iris diaphragm (*D*, fig. 39) successfully solved the problem. In the apparatus as used the test object is located 170 cm. from the eye of the subject. The diaphragm *D* is 31 cm. from the subject's eye. Thus, when he accommodates for the distance of the test object, the edge of the diaphragm is very hazy and indefinite. By reducing the opening in the diaphragm to a diameter of 12 mm. and properly placing the tube and the artificial pupil in relation to the diaphragm and the test object, the subject was unable to see any of the circular frame surrounding the test field and could not see the entire field. The portion exposed to view was circular, with indefinite edges and approximately 7.5 cm. in diameter. This reduced to a negli-

[1] Ives, Abstract Bulletin of the Physical Laboratory of the National Electric Lamp Asso., 1913, 1, opp. p. 36.

bearings so that it could revolve freely. A light aluminum arm $A$, fastened to the eccentric, extended from the axis of rotation a distance of 25 cm. This arm resting against a suitable catch $C$ held the eccentric in a position above its center of gravity and ready to be tipped over to the left by the offset $O$ carried by the wheel $W$. When the eccentric was lifted from the catch $C$, and pushed slightly past its highest position by $O$, which moved from right to left, it then fell of its

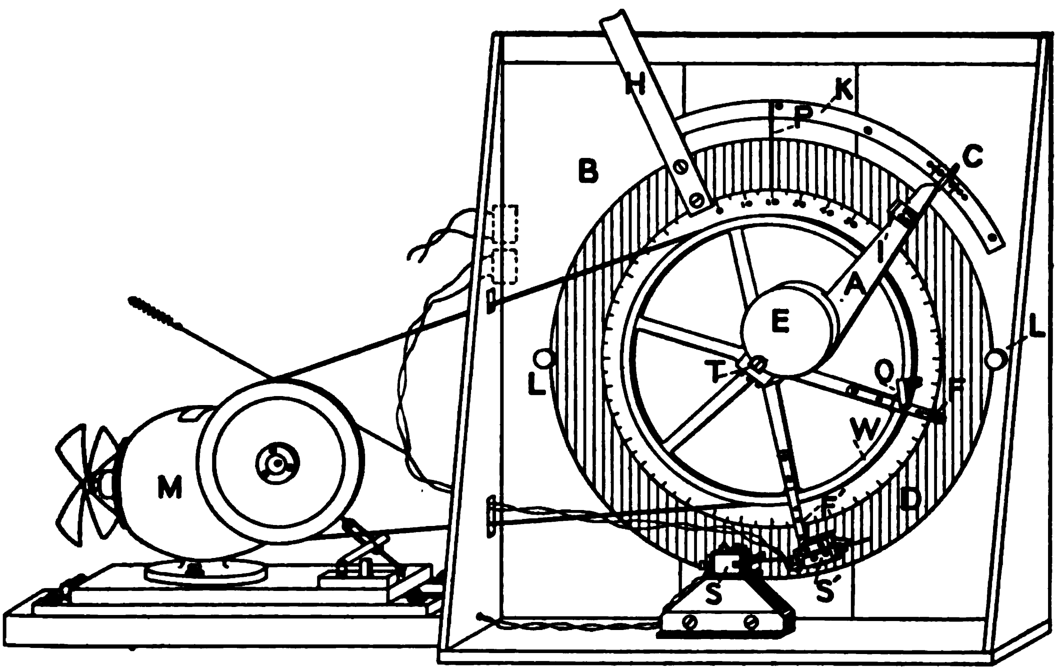


FIG. 44.—Diagram of the automatic pendulum key used to regulate the length of the electric shocks employed as stimuli.

$T$, a rigid stud (mounted in the heavy base, $B$) about which the eccentric, $E$, bearing the extension arm, $A$, may revolve; $M$, a worm-gear motor revolves wheel, $W$, from right to left, and the offset, $O$, carries the arm, $A$, from its position of rest, causing it to fall to the left; $S$ and $S'$, two switches opened by $A$; $C$, catch device for retaining $A$ after its fall; $F$ and $F'$, feet mounted on $W$ and used to close switches, $S$ and $S'$, respectively, preparatory to the next shock; $I$, insulation material on the arm, $A$; $S'$ is mounted on the large disk, $D$, which is movable by the handle, $H$. By the scale and pointer, $P$, mounted on the arc, $K$, the switches may be set to certain degrees of separation and the disk clamped by lugs, $L$. The relative size of the instrument may be gaged by the size of the disk, $D$, which is 46 cm. in diameter.

own accord and with a very swift movement, opened the two switches $S$ and $S'$, and carried through to the catch $C$. The contacts at $S$ and $S'$ were so devised that when struck open they remained in this position unless released by pressure from the feet $F$ and $F'$ carried by the wheel $W$. The contact $S$ was closed by the foot $F$ and was always closed before $S'$ so as to reestablish the short circuit $P$, figure 43. The con-

The subject very easily understood his task. He had to be especially warned, however, to hold his head still by keeping it pressed firmly against the rest and biting on the soft wooden peg with his teeth. He was repeatedly told that he must make his eye do all the moving and that he should see one mark clearly before looking for the other. The subject was instructed also to refrain from winking at the time of moving

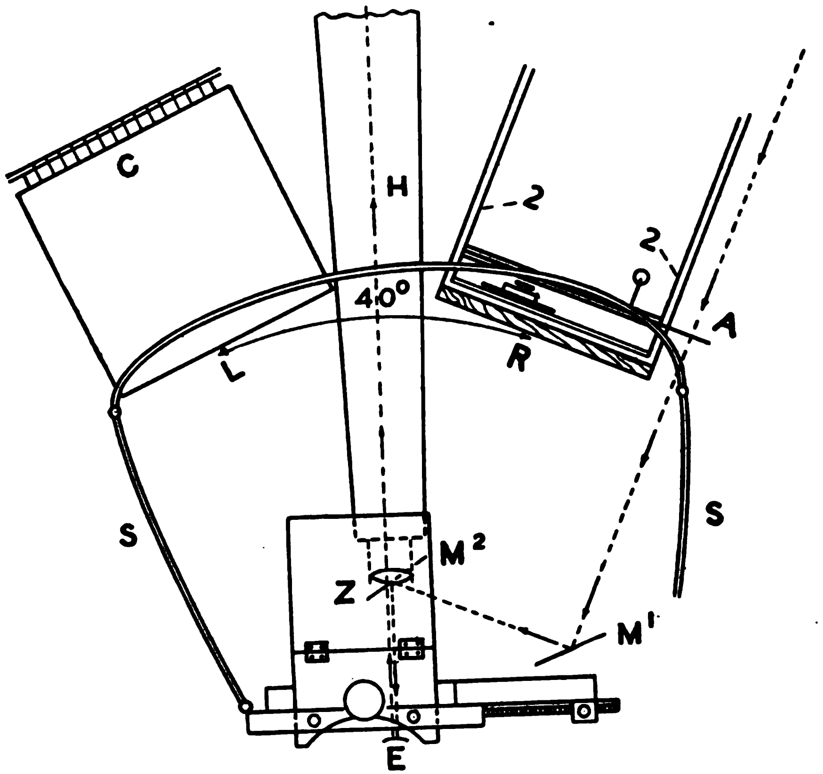


FIG. 50.—Ground plan of the apparatus and arrangement for photographing eye movements.

*S*, black screen surrounding the subject's field of view; *R* and *L*, right and left fixation marks separated by 40°; *H*, hood of camera; *Z*, lens in front of subject's eye, *E*; $M^1$ and $M^2$, mirrors for reflecting beam of light indicated by arrows; 2, frame carrying shield, *A*, drops down and exposes eye to light as signal for movements to begin; *C*, cords for operating eye-reaction, stimulus device. The camera, located at the other end of the hood *H*, is not indicated in the diagram.

the eye.[1] The black screen which enclosed the subject's field of view (*S*, figure 50; *B*, figure 35) was of particular service in eliminating all distracting objects, so that it was unnecessary to warn the subject to refrain from looking at other objects than the correct fixation-points.

Two series of movements were recorded on each photographic plate. The camera was moved slightly to one side at the beginning of the sec-

[1]Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 81.

The intersection of the dark and light bands with the border is more prominent at positions 1 and 3 than at 2 and 4. By this intersection phenomenon, many subjects are able to judge correctly the axial direction of bands before being able to see them at the black fixation dot in the center of the field. See p. 173 for method of avoiding this difficulty.

Fig. 51.—Full-size reproduction of a portion of the visual-test object window.

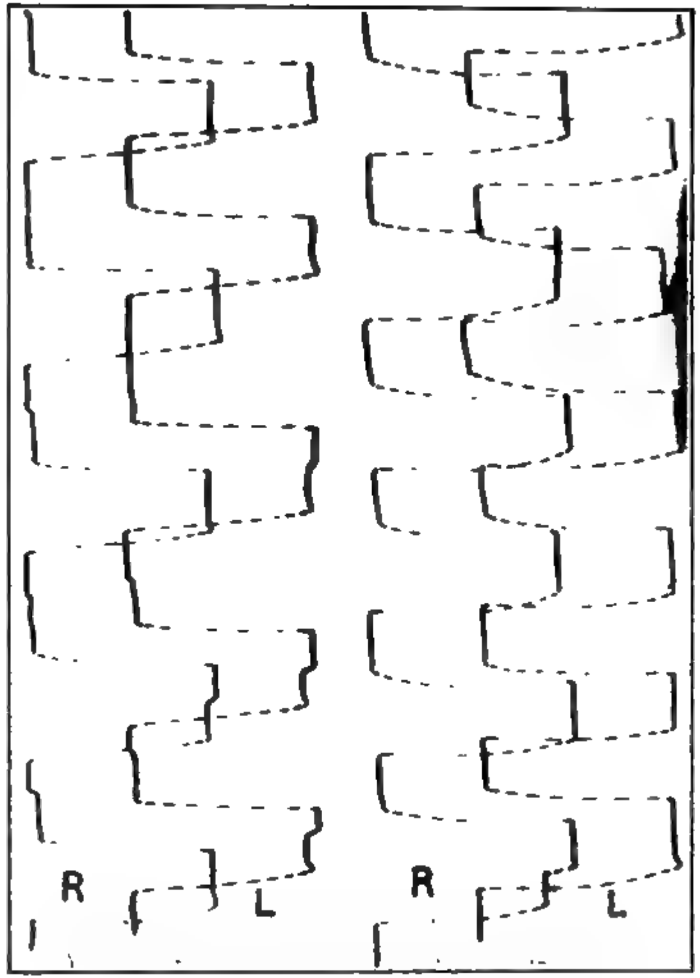


Fig. 52.—Sample eye-movement records, unretouched, reproduced nearly full size from contact prints of the original plates.

circuit is opened every 2 seconds by the swing of the pendulum in a large Seth Thomas clock. When the clock pendulum opens the contact in the primary circuit, a spark from the tip of the metal pointer dislodges the smoke in the immediate vicinity on the kymograph paper, and so incorporates time intervals directly with the record. The speed of the kymograph drum *D* was 50 mm. per second, and as its periphery represents the distance of 500 mm., it was convenient to make the finger-movement series 10 seconds long. Movements were counted in five 2-second blocks. Three series of movements were recorded, with a rest interval of at least 1 minute. Ten sec-

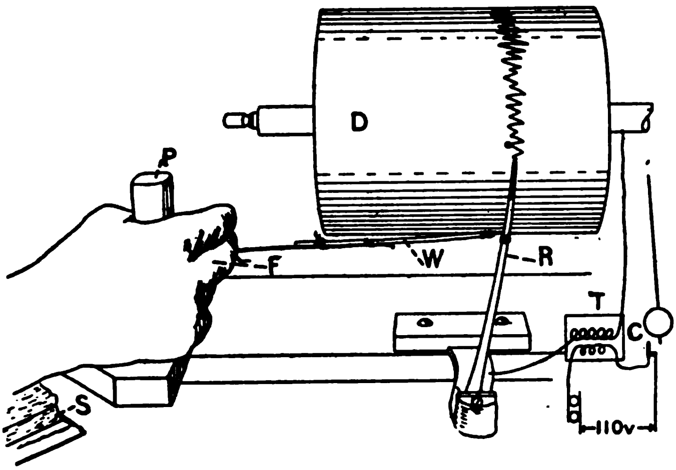


FIG. 53.—Schematic representation of apparatus and hand in position for recording finger movements.

*S*, support for wrist and arm; *P*, post to be gripped; *F*, finger connection to recording point, *R*, by insulation material, *W*; *T*, induction apparatus of commercial design with high tension winding connected to kymograph drum, *D*, and metal recording point, *R*; *C*, pendulum of large clock to break primary circuit of transformer and so, by the jump sparks, record time directly on the finger movement record.

onds at maximum finger movement speed is not so long as to be fatiguing. The subject was allowed to use whatever amplitude of movement he thought consistent with his best performance. The tracing was to be a record of finger movements and not of hand or arm movements. For this cause the subject was instructed to grip the post *P* rather tightly. The first and second fingers of the hand were moved together simultaneously, a form of movement which Langfeld[1] has shown favors the greatest speed. Sections of finger-movement records may be seen in figure 29, page 158. It was experimentally expedient to place the finger-movement records on the same kymograph sheet with the others taken in room B. They could be traced over the word reactions without causing any particular

[1] Langfeld, Psychol. Review, 1915, 22, p. 453.

TABLE 9.—*Comparison of body-weights with normal standards, Squad A.*

| Subject. | Age. | Height (Sept. 29, 1917). | (a) Normal weight for age and height.[1] | (b) Initial weight (Sept. 30, 1917). | (c) Difference between normal and initial weights (b-a). | (d) Minimum weight. | (e) Difference between normal and minimum weights (a-d). | (f) Greatest loss (b-d). | (g) Weight 20 per cent less than normal. | (h) Difference between minimum and 20 per cent limit (d-g). |
|---|---|---|---|---|---|---|---|---|---|---|
| | *yrs.* | *cm.* | *kg.* | *kg.* | *kg.* | *kg.* | *kg.* | *kg.* | *kg.* | *kg.* |
| Bro..... | 26 | 167 | 60.3 | 61.8 | + 1.5 | 54.0 | − 6.3 | 7.8 | 48.2 | + 5.8 |
| Can..... | 26 | 177 | 67.5 | 79.8 | +12.3 | 68.8 | + 1.3 | 11.0 | 54.0 | +14.8 |
| Kon..... | 20 | [2]168 | 58.3 | [3]69.0 | +10.7 | 60.3 | + 2.0 | 8.7 | 46.6 | +13.7 |
| Gar..... | 22 | 171 | 61.4 | 71.3 | + 9.9 | 62.3 | + 0.9 | 9.0 | 49.1 | +13.2 |
| Gul..... | 24 | 166 | 59.2 | 66.8 | + 7.6 | 59.0 | − 0.2 | 7.8 | 47.4 | +11.6 |
| Mon.... | 32 | 171 | 64.7 | 68.8 | + 4.1 | 59.5 | − 5.2 | 9.3 | 51.8 | + 7.7 |
| Moy.... | 23 | 174 | 64.0 | 63.5 | − 0.5 | 56.0 | − 8.0 | 7.5 | 51.2 | + 4.8 |
| Pea..... | 21 | 169 | 59.7 | 69.3 | + 9.6 | 60.0 | + 0.3 | 9.3 | 47.8 | +12.2 |
| Pec..... | 44 | 170 | 66.5 | 64.3 | − 2.2 | 57.8 | − 8.7 | 6.5 | 53.2 | + 4.6 |
| Spe..... | 19 | 171 | 59.6 | 63.5 | + 3.9 | 55.3 | − 4.3 | 8.2 | 47.7 | + 7.6 |
| Tom.... | 25 | 176 | 66.3 | 59.5 | − 6.8 | 54.3 | −12.0 | 5.2 | 53.0 | + 1.3 |
| Vea..... | 22 | 175 | 64.2 | 65.8 | + 1.6 | 58.3 | − 5.9 | 7.5 | 51.4 | + 6.9 |
| Fre..... | 25 | 167 | 59.9 | 57.5 | − 2.4 | .... | ...... | .... | .... | ...... |

[1] Normal weight based on table 4 in report of the Medico-Actuarial Mortality Investigation, 1912, 1, p. 38, deducting 8 lbs. for clothing.
[2] Height obtained Oct. 7, 1917.
[3] Weight obtained Oct. 28, 1917; weight on Oct. 7 was 67.3 kg.

TABLE 10.—*Comparison of body-weights with normal standards, Squad B.*

| Subject. | Age. | Height (Oct. 7, 1917). | (a) Normal weight for age and height. | (b) Weight on Oct. 7, 1917. | (c) Difference between normal weight and weight on Oct. 7, 1917 (b-a). | (d) Weight on Jan. 6, 1918. | (e) Difference between normal weight and weight of Jan. 6, 1918. (d-a). | (f) Difference between weight on Oct. 7, 1917, and weight of Jan. 6, 1918. (d-b). | (g) Final or minimum weight with reduced diet (Jan. 28, 1918). | (h) Difference between normal weight and final or minimum weight (g-a). |
|---|---|---|---|---|---|---|---|---|---|---|
| | *yrs.* | *cm.* | *kg.* | *kg.* | *kg.* | *kg.* | *kg.* | *kg.* | *kg.* | *kg.* |
| Fis...... | 27 | 177 | 67.5 | 76.0 | +8.5 | 76.3 | + 8.8 | +0.3 | 71.7 | +4.2 |
| Har..... | 20 | 175 | 63.3 | 63.0 | −0.3 | 63.7 | + 0.4 | +0.7 | 59.1 | −4.2 |
| How.... | 19 | 179 | 65.5 | 70.0 | +4.5 | 72.0 | + 6.5 | +2.0 | 66.2 | +0.7 |
| Ham.... | 20 | 184 | 70.4 | 75.0 | +4.6 | 74.8 | + 4.4 | −0.2 | 69.9 | −0.5 |
| Kim..... | 25 | [1]176 | 66.3 | .... | ..... | 61.9 | − 4.4 | ..... | 59.9 | −6.4 |
| Lon..... | 22 | 179 | 67.1 | 66.8 | −0.3 | [2]67.8 | + 0.7 | +1.0 | 63.3 | −3.8 |
| Sch...... | 29 | [1]166 | 60.5 | .... | ..... | 68.6 | + 8.1 | ..... | 63.8 | +3.3 |
| Liv...... | 18 | 161 | 51.8 | 60.5 | +8.7 | 63.6 | +11.8 | +3.1 | 58.6 | +6.8 |
| Sne..... | 22 | 175 | 64.2 | 72.3 | +8.1 | 72.9 | + 8.7 | +0.6 | 67.7 | +3.5 |
| Tho..... | 24 | 179 | 68.0 | 62.0 | −6.0 | 63.2 | − 4.8 | +1.2 | 59.3 | −8.7 |
| Van..... | 24 | 179 | 68.0 | 67.3 | −0.7 | 69.8 | + 1.8 | +2.5 | 64.8 | −3.2 |
| Wil...... | 19 | 164 | 54.6 | 58.5 | +3.9 | 59.8 | + 5.2 | +1.3 | 56.9 | +2.3 |

[1] Height obtained Jan. 5, 1918; age computed for date of Jan. 5, 1918, and not for Oct. 7, 1917, as with the other subjects.
[2] Weight obtained Dec. 16, 1917; Lon did not come to Boston with Squad B on Jan. 6, 1918.

them in the form of curves to show several important things, first, the loss in body-weight at the beginning of the experiment during the period of reduction in diet; second, the approximately constant level of body-weight during the period of partial realimentation; third, the not insignificant alterations in body-weight following the unavoidable, but regrettable, periods of unrestricted diet, *i. e.*, occasional Sundays, four days at the Thanksgiving season,[1] and 18 days at the Christmas recess; finally, the astonishing increase in body-weight incident to the complete withdrawal of all dietetic restrictions after February 4, 1918. Since this picture is so pronounced, it has been deemed advisable to plot an individual weight curve for each man in both Squad A and Squad B. In considering these curves, it should be remembered that the Thanksgiving recess was from November 29 to December 2, inclusive, and the Christmas recess from December 20 to January 6, inclusive, although some of the men did not return to college until later.

## BODY-WEIGHT CURVES OF SQUAD A.

### Body-weight curve of Bro (Fig. 57).

Prior to the reduction in diet, *Bro* had a weight of 61.8 kg. The next record of weight was not taken for about two weeks, during which time there had been a material curtailment of diet, but the weight had dropped to only 61 kg. Subsequently, owing to the restriction in diet,

Fig. 57.—Body-weight curve of *Bro*.

the weight decreased in a reasonably regular manner until the unrestricted meal of November 25, after which there was a rise of approximately 1 kg. On December 9 the weight had fallen to a lower level

[1] The absence of a pronounced change in weight after Thanksgiving was doubtless due to the fact that records of the body-weight were not made until December 4, and the men had trained for a loss in weight to counterbalance the gain during the Thanksgiving recess.

But one post-diet record of weight was obtained for this man, showing that in 4 days the body-weight increased nearly 6 kg. This rapid increase in body-weight must have been due in large part to an increase in the water content of the body, for an addition of 6 kg. of organized muscle or fat would have been impossible during this short time.

BODY-WEIGHT CURVE OF GAR (FIG. 60).

The weight for *Gar* prior to the restricted diet was 71.25 kg. With the reduced diet there was a consistent and steady fall in the curve until the first record after November 11, which showed the rise commonly found after the unrestricted Sunday meal. The weight then continued to fall and showed no increase during the Thanksgiving

Kgs.

FIG. 60.—Body-weight curve of *Gar*.

recess. A great increment appeared when higher feeding was resumed. During the Christmas recess there was a gain of 5.8 kg. This was followed by a rather rapid fall incidental to an extremely low ingestion of food on the return to college, varied by one or two sharp rises. The last 15 days the weight fluctuated around 64 kg., which was evidently *Gar's* lower limit of weight. During the post-diet period there was the usual rapid rise in body-weight, with a total gain of 9.5 kg. When the measurements ceased, the subject was somewhat more than 1 kg. heavier than at the beginning of the observations.

BODY-WEIGHT CURVE OF GUL (FIG. 61).

The first part of the curve for *Gul* follows the same course as the other curves thus far examined. The slight rise after the unrestricted

[illegible] on Sunday, November 11, is again noted; also an increase on November 25. The lower weight-level is evidently not far from 60 kg. In spite of the fact that the recorded weights for this subject show an increase of only 1 kg. during the Christmas vacation, it should be stated that, according to the report of the subject, very large increases and decreases in weight were observed during this time. The subject reported one increase of 5.9 kg., which necessitated a rapid reduction by exercise and purgatives. On returning to college, he voluntarily took a very low diet of approximately 1,000 calories, but

Fig. 61.—Body-weight curve of *Gul.*

even under these conditions there was an increase in weight, probably due to an increase in the water content of the body. During the final two or three weeks the body-weight fluctuated either side of 60.5 kg., which is not far from his minimum value. At the conclusion of the experiment the usual rapid rise in body-weight was observed, until the subject had reached a level nearly 3 kg. higher than the initial weight in September. This subject was noted among his colleagues as a heavy eater. His potentialities for consuming large quantities of food are indicated by the typical day's record selected from his report of unrestricted diet, which shows the large number of calories usually taken on the free days. (See table 33, p. 269.)

### Body-weight curve of Mon (Fig. 62).

Perhaps no subject in the whole squad adhered so rigidly to dietetic control as did *Mon.* He was a wrestler, and was rather anxious to secure a lower weight so that he might enter a lower wrestling class

tively the largest increase that occurred in the whole series of observations of body-weight, *i. e.*, 21.2 per cent of his weight on February 3. This subject gained 12.25 kg. in slightly over a month. It is worthy of note that this is one of the subjects who was slightly under the normal weight at the beginning of the experiment. When the records for this


FIG. 63.—Body-weight curve of *Moy*.

subject ceased on March 14, that is, approximately six weeks after the end of the diet experiment, he weighed 6.5 kg. more than at the beginning of the observation in September.

BODY-WEIGHT CURVE OF PEA (FIG. 64).

*Pea* was distinctly of an athletic temperament and build, exercised a great deal, and lost weight rapidly on a restricted diet, falling from his initial weight of 69.25 kg. to 61.25 kg. on November 11. The first upward break in the curve occurred immediately thereafter in common with most of the subjects after the unrestricted meals on the Sundays in Boston. Until December 20 the body-weight fluctuated about this point, which was evidently a basal minimum. In the Christmas recess there was an increase of 6 kg., followed by a rapid fall on a very much restricted diet, with a fluctuating but slower fall thereafter to the end of the experiment. In the last week the body-weight

remained constant at approximately 61.5 kg. With the resumption of free diet a very large increase in body-weight occurred. From February 3 to March 14 this subject gained in weight 12.7 kg., the record for the last date being actually 4.75 kg. greater than at the beginning of the experiment in September.

FIG. 64.—Body-weight curve of *Pea.*

BODY-WEIGHT CURVE OF PEC (FIG. 65).

*Pec* was one of the subjects who was definitely under the normal weight at the beginning of the experiment. He was an unusually well-trained man, 44 years of age, and found great difficulty in losing weight. Even on a very restricted diet the weight curve did not fall so rapidly as one would expect. When at home, and also on a free Sunday, he found difficulty in limiting the amount eaten, as may be noted subsequent to November 11, when there was the usual gain of weight following a free day. Under strict training, however, he lowered his body-weight until he finally reached a minimum of 57.75 kg. on December 9. Throughout the month of December the weight was not far from 58.5 kg. at this lower level. A small increase was noted at the end of the Christmas recess, although, as the subject was for a week of this time on volunteer Y. M. C. A. duty at Camp Devens, he reported

on unrestricted diet a material increase in weight which was rapidly removed by severe training just prior to returning to college. During the last two or three weeks of the experiment the body-weight fluctuated somewhat above or below 59 kg. In the last week it had a tendency to be slightly below 59 kg. Owing to the great earnestness of this man, and the fact that the dietetic restrictions seemed to cause him considerable anxiety, it was necessary to be cautious about reducing the weight rapidly or to a great extent. It was finally

Kgs.

FIG. 65.—Body-weight curve of *Pec.*

decided that no attempt would be made to have him lose the 10 per cent expected of the other subjects. Greatly to his satisfaction, however, he succeeded in reaching the 10 per cent lower level, but he was not allowed to go below this weight. His earnestness of purpose and desire to hold his lower weight-limit are seen by the small number of calories that he consented to live upon during the last few weeks of the experiment. The usual rapid post-diet rise was observed for this subject, also. Between February 3 and March 14 there was an increase of somewhat over 12 kg., the final weight being more than 7 kg. above the initial weight in September.

### Body-weight curve of Spe (Fig. 66).

Although *Spe* could not complete the experiment, owing to an unforeseen and unfortunate illness which necessitated the observations being stopped on December 13, his body-weight curve indicates a consistent regular loss until November 11, when there was the usual

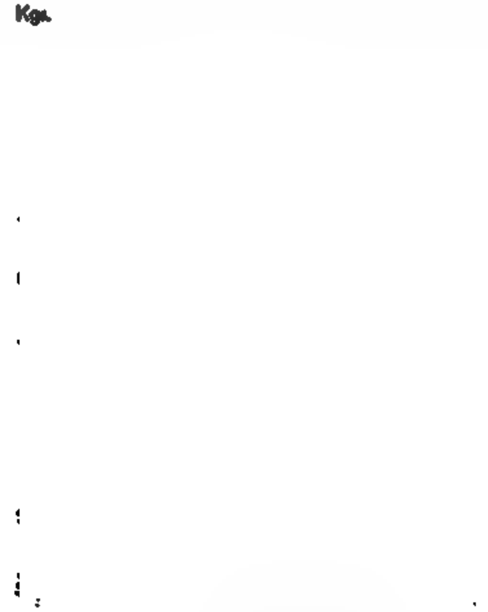


Fig. 66.—Body-weight curve of *Spe*.

noticeable rise. There was also a rise after the unrestricted meal on November 25, with a tendency for the weight to remain at the lower level of approximately 56 kg. during the period between November 11 and December 13. To hold him at this weight it was necessary to increase the calories to approximately 2,250 calories.

### Body-weight curve of Tom (Fig. 67).

One of the most sedentary men in the whole squad was *Tom*, who was under normal weight at the beginning of the experiment. His duties in the college store prevented his taking a large amount of exercise and he found great difficulty in reducing his weight on the diet supplied to the other men. Consequently the fall in the body-weight curve is much slower than with the other subjects. There is, however, the characteristic rise after November 11 and another after November 25, both of these after the unrestricted diet on the Sundays following the Boston experiments. Subsequently, however, until the beginning of the Christmas recess, his body-weight remained essentially constant at about 55.5 kg. During the Christmas recess he was at home and was operated upon for hemorrhoids. He thus underwent

### EFFECT OF UNRESTRICTED MEALS.

One of the most perplexing factors in the whole research was the unrestricted meals allowed Squad A, *i. e.*, those taken Sunday noon after the biweekly experiment in Boston, and the diet during the Thanksgiving and Christmas recesses. The academic program made it possible for many of these men to go to their homes every two weeks. Under these conditions they would take their meals at the family table and, on account of the apprehension of parents and friends, it was almost obligatory for the men to eat more food than was commonly served at the diet table. After considerable discussion it was deemed absolutely essential to allow these men unrestricted diet on these days, but they were especially cautioned to curtail so far as possible the consumption of protein. The men consented to report in writing to the best of their knowledge the food eaten in the unrestricted meals

Fig. 68.—Body-weight curve of *Vea*.

on the alternate Sunday noons. It will be recalled that they were given a standardized laboratory breakfast and the Sunday evening meal was usually very light; hence, the chief extra energy was obtained in the Sunday noon dinner.

With nearly every man there was a perceptible increase in the body-weight following the free meal, this increase frequently amounting to as much as 1 kg. In the curves for all of the subjects but *Bro*, the first actual rise occurs shortly after the unrestricted day November 11–12. We thus have a definite rise in weight, which can be ascribed solely to

of the vacation to reduce their weight, and several (*Mon*, *Pec*, and *Gul*) abstained from food entirely on January 5 and 6. It must be remembered, therefore, that the weights recorded in the curves for January 7 by no means represent the maximum increase during the Christmas recess as a result of the freedom from the restricted diet.

### BODY-WEIGHT CURVES OF SQUAD B.

From the data already given in table 10 it can be seen that most of the men in Squad B had a tendency to increase in weight during the academic year. These increases are shown in the body-weight curves for the men in Squad B (figs. 69 to 73). With *Har*, *Fis*, *Sne*, and *Lon* there was considerable fluctuation in the weight prior to the dietetic restriction, but in general the body-weight tended to increase. The extreme regularity of the curve following the dietetic restriction is, however, strikingly significant. These men were all given a diet containing approximately 1,400 net calories. The resultant fall in body-weight is markedly uniform and to such a degree that the curves might almost be superimposed in many instances. When one considers that we deal here with men of varying initial weights and varying activities, this uniformity is indeed surprising. An exception to this uniform fall in weight is shown by the curve for *Kim*, whose loss in weight was less than that for any of the other men in Squad B. *Kim* was, however, one of the men who was most deficient

Kgs.

FIG. 69.—Body-weight curves of *Fis*, *Ham*, and *Sne*.

Kgs.

FIG. 70.—Body-weight curves of *How*, *Van*, and *Lon*.

Kgs.

FIG. 71.—Body-weight curves of *Har* and *Wil*.

Kgs.

FIG. 72.—Body-weight curves of *Tho* and *Liv*.

TABLE 11.—*Percentage losses in body-weight of Squads A and B.*

[1] Weight obtained Oct. 28, 1917; weight on Oct. 7 was 67.3 kg.
[2] Weight obtained Dec. 16, 1917; *Lon* did not come to Boston with Squad B on Jan. 6, 1918.
[3] Weight obtained on Dec. 13 just before subject left the squad.

mum loss was again found with *Tom*, with a percentage loss of 7.4 per cent. The average loss for the entire squad was 10.5 per cent. This is of special interest, as it will be recalled that the effort was made to secure an average loss in weight for these men of 10 per cent, and all of the men, except *Tom*, were able to reduce their weight to this extent. *Pec* found this reduction difficult, but was finally able to exceed the 10 per cent limit slightly. Thereafter he was given a little more freedom in diet, with a consequent increase in weight, so that the loss at the end of the experiment was but 8.1 per cent.

The diet experiment with Squad B continued for but three weeks. The loss recorded at the end of the period ranged from a minimum of 2 kg. with *Kim* to a maximum of 5.8 kg. with *How*. Aside from the low values found with *Kim* and *Wil*, there is a striking uniformity in the losses of the members of this squad. The percentage losses show this general uniformity clearly. If we exclude the percentage losses for *Wil* of 4.8 per cent and *Kim* of 3.2 per cent, the range is from *How*, 8.1 per cent, to *Fis*, 6.0 per cent, with a general average loss of 6.5 per cent.

## POST-DIET INCREASES IN BODY-WEIGHT OF SQUAD A.

Although numerous experiments could be made upon a squad of men at the lower nutritional level and during the recuperation period, it was impracticable to make further observations, since a number of

TABLE 13.—*Body-surface measurements (Du Bois) for Squad A.*

| Subject and date. | A | B | F | G | H | I | J | K | L | M | N | P | Q | W | R | S | T | U | V | Area computed from formula. | Body-weight without clothing. | Height. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *sq. m.* | *kg.* | *cm.* |
| BRO. | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 29.. | 63.0 | 55.0 | 55.5 | 30.0 | 26.4 | 16.0 | 18.7 | 20.8 | 51.5 | 73.1 | 84.9 | 52.6 | 90.3 | 44.5 | 45.1 | 34.0 | 25.3 | 23.5 | 21.0 | 1.69 | 61.8 | 167.2 |
| Nov. 24.. | 64.0 | 55.4 | 55.5 | 27.1 | 25.0 | 15.0 | 18.3 | 20.6 | 53.0 | 67.0 | 80.7 | 49.5 | 85.9 | 44.0 | 45.5 | 33.0 | 25.8 | 22.5 | 20.3 | 1.62 | 55.5 | 166.4 |
| Feb. 2.. | 64.5 | 55.0 | 56.4 | 27.2 | 25.3 | 15.2 | 18.5 | 20.8 | 51.6 | 67.0 | 81.0 | 49.7 | 85.8 | 43.0 | 45.5 | 33.5 | 25.5 | 23.0 | 19.5 | 1.61 | 55.5 | 166.7 |
| CAN. | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 29.. | 66.8 | 56.5 | 59.2 | 33.2 | 28.4 | 18.4 | 20.9 | 22.2 | 60.4 | 86.5 | 94.7 | 60.1 | 99.0 | 42.0 | 49.7 | 36.5 | 26.9 | 24.0 | 23.5 | 2.03 | 79.8 | 176.9 |
| Nov. 24.. | 66.2 | 55.4 | 60.0 | 29.3 | 26.7 | 17.0 | 20.7 | 22.1 | 59.5 | 75.7 | 87.2 | 55.5 | 92.4 | 41.0 | 49.3 | 35.0 | 27.5 | 23.1 | 22.5 | 1.87 | 70.5 | 177.1 |
| Feb. 2.. | 66.7 | 55.2 | 59.1 | 30.0 | 26.5 | 17.6 | 20.2 | 22.0 | 57.5 | 76.2 | 88.1 | 55.0 | 95.0 | 41.7 | 48.6 | 35.6 | 27.5 | 23.0 | 22.2 | 1.86 | 70.3 | 177.5 |
| KON. | | | | | | | | | | | | | | | | | | | | | | |
| Oct. 27.. | 69.0 | 57.3 | 59.0 | 32.0 | 28.2 | 17.2 | 20.5 | 20.9 | 56.5 | 74.0 | 90.7 | 57.5 | 93.1 | 39.0 | 46.4 | 36.8 | 25.3 | 23.5 | 21.3 | 1.83 | 69.0 | 167.2 |
| Nov. 24.. | 66.1 | 58.2 | 58.5 | 29.4 | 27.4 | 16.7 | 20.5 | 20.6 | 56.2 | 70.8 | 85.7 | 53.5 | 89.0 | 39.7 | 46.0 | 34.3 | 27.0 | 23.0 | 21.3 | 1.75 | 65.0 | 167.6 |
| Feb. 2.. | 68.6 | 58.1 | 57.1 | 29.9 | 27.2 | 16.5 | 19.7 | 21.0 | 55.4 | 71.0 | 84.4 | 52.2 | 88.1 | 40.6 | 46.1 | 33.6 | 25.3 | 23.1 | 20.4 | 1.72 | 62.2 | 167.6 |
| GAR. | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 29.. | 67.8 | 56.7 | 55.2 | 31.7 | 28.2 | 18.5 | 20.5 | 22.0 | 56.0 | 77.6 | 94.5 | 57.2 | 93.0 | 42.8 | 45.4 | 35.4 | 26.2 | 23.0 | 22.5 | 1.86 | 71.3 | 170.5 |
| Nov. 24.. | 66.2 | 56.4 | 54.8 | 28.7 | 26.3 | 17.5 | 20.3 | 21.1 | 58.6 | 70.3 | 88.0 | 51.8 | 87.8 | 40.2 | 43.8 | 32.6 | 26.7 | 23.3 | 21.5 | 1.74 | 64.0 | 171.5 |
| Feb. 2.. | 66.1 | 56.4 | 54.2 | 29.7 | 26.8 | 17.7 | 20.5 | 21.4 | 57.8 | 70.0 | 87.6 | 51.7 | 88.6 | 40.0 | 44.2 | 33.1 | 26.5 | 23.7 | 21.7 | 1.74 | 63.9 | 171.1 |
| GUL. | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 29.. | 67.5 | 55.4 | 56.7 | 33.5 | 28.1 | 18.2 | 20.2 | 22.4 | 51.2 | 79.5 | 88.7 | 58.3 | 94.1 | 43.7 | 46.0 | 35.5 | 24.8 | 23.0 | 21.7 | 1.81 | 66.8 | 166.0 |
| Nov. 24.. | 65.5 | 55.5 | 56.0 | 28.5 | 26.5 | 17.0 | 20.0 | 21.5 | 51.2 | 74.0 | 83.0 | 54.5 | 89.5 | 43.7 | 47.0 | 34.0 | 25.0 | 23.0 | 21.2 | 1.71 | 61.0 | 164.8 |
| Feb. 2.. | 64.6 | 54.7 | 54.4 | 30.1 | 26.4 | 17.2 | 19.7 | 21.6 | 52.7 | 76.3 | 83.1 | 55.7 | 90.5 | 43.1 | 45.4 | 33.6 | 25.4 | 24.2 | 21.3 | 1.72 | 61.8 | 165.9 |
| MON. | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 29.. | 69.0 | 59.5 | 56.5 | 32.2 | 27.5 | 16.8 | 19.9 | 21.0 | 58.1 | 77.7 | 91.5 | 55.0 | 90.8 | 46.3 | 44.8 | 34.0 | 25.5 | 22.8 | 21.0 | 1.88 | 68.8 | 170.5 |
| Nov. 24.. | 69.1 | 58.3 | 56.5 | 30.0 | 25.8 | 16.6 | 20.7 | 20.7 | 57.0 | 71.2 | 86.4 | 49.2 | 86.6 | 45.0 | 44.3 | 33.5 | 26.3 | 21.5 | 20.3 | 1.76 | 61.5 | 170.5 |
| Feb. 2.. | 68.3 | 58.5 | 56.7 | 30.2 | 26.0 | 16.5 | 20.0 | 20.8 | 57.6 | 73.2 | 87.7 | 49.7 | 86.7 | 44.3 | 44.2 | 34.2 | 26.3 | 22.2 | 20.3 | 1.78 | 61.4 | 170.5 |
| MOY. | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 29.. | 66.7 | 60.3 | 57.0 | 28.5 | 25.6 | 16.3 | 20.0 | 21.1 | 56.1 | 71.8 | 87.0 | 53.6 | 90.5 | 43.0 | 48.7 | 35.2 | 26.0 | 23.9 | 21.0 | 1.79 | 63.5 | 174.3 |
| Nov. 24.. | 67.8 | 60.0 | 59.0 | 26.6 | 24.1 | 15.3 | 19.8 | 21.0 | 56.0 | 65.0 | 83.5 | 47.7 | 84.2 | 43.2 | 48.3 | 34.1 | 25.8 | 21.5 | 19.9 | 1.70 | 57.0 | 175.4 |
| Feb. 2.. | 67.3 | 59.5 | 57.5 | 25.5 | 24.2 | 15.6 | 19.6 | 21.2 | 55.8 | 67.5 | 83.2 | 49.2 | 86.1 | 43.2 | 45.3 | 33.3 | 25.8 | 22.5 | 20.2 | 1.68 | 58.5 | 174.3 |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PEA. | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 29.. | 69.2 | 58.5 | 54.5 | 33.5 | 27.8 | 18.3 | 20.2 | 21.5 | 56.4 | 76.3 | 95.5 | 55.8 | 95.3 | 41.8 | 46.5 | 36.9 | 25.5 | 23.3 | 22.3 | 1.88 | 69.3 | 168.5 |
| Nov. 24.. | 67.3 | 58.5 | 53.6 | 30.8 | 25.7 | 17.1 | 19.6 | 20.8 | 55.8 | 69.8 | 90.5 | 51.3 | 90.2 | 41.0 | 45.9 | 34.1 | 25.6 | 23.1 | 21.5 | 1.74 | 62.8 | 169.1 |
| Feb. 2.. | 68.7 | 59.7 | 55.4 | 29.5 | 26.3 | 17.2 | 19.0 | 21.1 | 54.4 | 72.0 | 91.0 | 52.0 | 90.0 | 41.5 | 46.2 | 35.2 | 25.8 | 23.1 | 21.4 | 1.76 | 62.3 | 169.0 |
| PEC. | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 29.. | 65.8 | 56.9 | 57.8 | 28.8 | 26.5 | 17.0 | 20.6 | 22.7 | 58.5 | 73.0 | 87.7 | 53.5 | 91.0 | 42.1 | 49.0 | 36.5 | 25.5 | 24.1 | 22.0 | 1.84 | 64.3 | 170.1 |
| Nov. 24.. | 66.1 | 56.9 | 58.6 | 26.1 | 25.1 | 16.4 | 20.8 | 21.6 | 56.7 | 67.6 | 84.6 | 49.9 | 85.7 | 42.2 | 47.7 | 35.8 | 26.5 | 23.0 | 21.3 | 1.74 | 60.0 | 170.7 |
| Feb. 2.. | 65.5 | 57.1 | 57.2 | 25.8 | 25.2 | 16.1 | 20.7 | 21.8 | 57.3 | 70.9 | 84.5 | 48.3 | 86.7 | 41.3 | 47.5 | 35.1 | 25.7 | 23.5 | 21.3 | 1.74 | 60.0 | 170.7 |
| SPE. | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 29.. | 65.3 | 55.7 | 58.5 | 30.0 | 25.3 | 16.5 | 20.8 | 20.6 | 55.2 | 73.3 | 88.7 | 55.5 | 90.3 | 42.5 | 47.7 | 35.5 | 25.0 | 22.8 | 20.8 | 1.79 | 63.5 | 171.1 |
| Nov. 24.. | 62.9 | 55.5 | 60.6 | 25.4 | 22.7 | 15.4 | 20.0 | 20.3 | 57.2 | 64.8 | 83.3 | 48.8 | 84.3 | 40.9 | 48.8 | 33.5 | 25.7 | 21.8 | 19.5 | 1.67 | 55.8 | 171.8 |
| TOM. | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 29.. | 62.0 | 56.5 | 59.5 | 28.5 | 25.2 | 17.0 | 21.0 | 21.2 | 57.2 | 67.8 | 89.0 | 52.0 | 86.5 | 44.8 | 49.0 | 34.7 | 25.5 | 22.8 | 21.0 | 1.79 | 59.5 | 175.6 |
| Nov. 24.. | 66.1 | 55.0 | 58.0 | 25.6 | 23.6 | 16.4 | 20.3 | 21.0 | 57.8 | 64.2 | 80.1 | 48.7 | 83.1 | 44.0 | 47.9 | 33.0 | 26.8 | 23.0 | 20.6 | 1.69 | 56.0 | 175.9 |
| Feb. 2.. | 66.7 | 56.1 | 57.5 | 26.1 | 23.4 | 16.8 | 19.5 | 21.0 | 56.5 | 64.5 | 81.5 | 48.5 | 84.0 | 43.0 | 48.5 | 33.0 | 26.1 | 22.5 | 20.3 | 1.67 | 55.9 | 175.5 |
| VEA. | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 29.. | 66.5 | 58.0 | 58.0 | 29.0 | 26.0 | 17.5 | 21.7 | 21.3 | 57.0 | 75.0 | 88.2 | 54.0 | 91.5 | 44.5 | 47.0 | 34.5 | 25.2 | 24.0 | 23.0 | 1.84 | 65.8 | 174.9 |
| Nov. 24.. | 65.6 | 57.9 | 58.2 | 26.9 | 24.4 | 17.2 | 21.1 | 20.7 | 56.1 | 68.3 | 83.6 | 49.8 | 87.1 | 43.5 | 46.2 | 33.6 | 26.3 | 22.5 | 21.7 | 1.72 | 60.3 | 174.3 |
| Feb. 2.. | 67.3 | 58.3 | 59.2 | 27.4 | 24.6 | 17.4 | 21.6 | 21.1 | 54.5 | 69.0 | 84.0 | 48.7 | 87.5 | 45.6 | 47.3 | 34.5 | 26.3 | 22.7 | 21.8 | 1.75 | 59.3 | 174.2 |

TABLE 14.—*Body-surface measurements (Du Bois) for Squad B.*

| Subject and date. | A | B | F | G | H | I | J | K | L | M | N | P | Q | W | R | S | T | U | V | Area computed from formula. | Body-weight without clothing. | Height. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FIS. | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *sq. m.* | *kg.* | *cm.* |
| Jan. 5.. | 69.8 | 58.3 | 56.9 | 32.9 | 28.9 | 18.3 | 21.2 | 22.4 | 58.2 | 79.9 | 93.6 | 58.0 | 98.3 | 38.6 | 48.0 | 37.0 | 26.3 | 23.7 | 22.3 | 1.93 | 76.3 | 176.1 |
| Jan. 27.. | 68.0 | 57.5 | 58.5 | 30.5 | 27.6 | 17.8 | 20.7 | 22.0 | 58.7 | 74.2 | 89.0 | 52.5 | 94.5 | 39.0 | 48.0 | 36.0 | 26.2 | 23.0 | 21.5 | 1.85 | 72.3 | 175.9 |
| HAR. | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 5.. | 64.9 | 54.9 | 58.2 | 30.4 | 28.2 | 17.5 | 20.4 | 22.1 | 58.0 | 71.5 | 88.4 | 57.5 | 91.1 | 43.2 | 46.1 | 35.3 | 25.0 | 23.2 | 21.7 | 1.83 | 63.7 | 173.9 |
| Jan. 27.. | 64.0 | 53.8 | 58.1 | 28.5 | 26.8 | 16.9 | 20.3 | 22.1 | 57.5 | 67.6 | 86.6 | 55.0 | 88.1 | 43.3 | 45.4 | 33.8 | 24.5 | 22.9 | 20.8 | 1.75 | 59.6 | 173.7 |
| HOW. | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 5.. | 66.7 | 57.5 | 59.2 | 31.1 | 28.0 | 17.1 | 20.4 | 21.6 | 58.2 | 77.3 | 93.5 | 59.0 | 99.1 | 41.4 | 51.0 | 36.7 | 27.0 | 24.8 | 23.4 | 1.95 | 72.0 | 178.3 |
| Jan. 27.. | 66.9 | 57.1 | 58.2 | 28.9 | 26.4 | 16.4 | 20.0 | 21.0 | 57.5 | 72.0 | 89.0 | 56.3 | 94.6 | 43.0 | 50.3 | 35.0 | 26.5 | 23.8 | 22.5 | 1.85 | 66.6 | 178.0 |
| HAM. | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 5.. | 69.5 | 59.5 | 61.6 | 32.2 | 27.2 | 17.3 | 21.0 | 20.6 | 59.9 | 77.7 | 93.6 | 59.9 | 99.4 | 44.5 | 47.8 | 33.8 | 26.5 | 23.4 | 21.1 | 1.97 | 74.8 | 183.2 |
| Jan. 27.. | 68.9 | 59.1 | 62.2 | 30.0 | 26.3 | 17.1 | 19.4 | 20.8 | 61.8 | 73.7 | 90.9 | 59.0 | 95.3 | 43.8 | 48.8 | 33.9 | 26.7 | 23.8 | 21.1 | 1.94 | 70.7 | 183.1 |
| KIM. | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 5.. | 69.2 | 57.2 | 61.4 | 27.5 | 26.0 | 15.1 | 20.6 | 19.6 | 55.7 | 73.0 | 85.4 | 51.0 | 89.7 | 43.8 | 49.7 | 34.3 | 25.5 | 23.0 | 20.7 | 1.78 | 61.9 | 175.6 |
| Jan. 27.. | 68.5 | 56.6 | 59.8 | 26.0 | 24.7 | 15.2 | 20.3 | 19.8 | 55.5 | 69.6 | 83.0 | 48.5 | 87.6 | 44.0 | 48.3 | 32.7 | 25.5 | 21.0 | 19.5 | 1.70 | 60.7 | 175.6 |
| SCH. | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 5.. | 69.1 | 56.1 | 55.8 | 32.2 | 28.7 | 18.0 | 21.2 | 22.6 | 53.5 | 74.6 | 97.4 | 55.5 | 93.0 | 42.5 | 44.6 | 36.2 | 26.5 | 24.0 | 21.4 | 1.84 | 68.6 | 166.0 |
| Jan. 27.. | 69.2 | 56.5 | 56.3 | 31.3 | 27.5 | 17.9 | 21.1 | 22.1 | 53.1 | 72.9 | 93.1 | 51.1 | 89.3 | 43.0 | 44.4 | 35.0 | 26.8 | 23.1 | 20.8 | 1.78 | 64.2 | 165.3 |
| LIV. | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 5.. | 66.7 | 58.1 | 54.0 | 30.8 | 26.7 | 17.2 | 18.4 | 19.1 | 55.9 | 74.8 | 92.1 | 56.3 | 92.1 | 38.3 | 41.8 | 32.9 | 24.0 | 22.3 | 20.2 | 1.71 | 63.6 | 161.1 |
| Jan. 27.. | 65.5 | 57.4 | 53.0 | 27.2 | 25.0 | 15.7 | 18.5 | 19.0 | 55.0 | 69.5 | 88.0 | 49.5 | 85.5 | 39.5 | 43.0 | 31.0 | 24.2 | 21.5 | 19.5 | 1.61 | 59.3 | 160.9 |
| SNE. | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 5.. | 65.0 | 54.8 | 58.2 | 32.5 | 28.5 | 18.0 | 19.5 | 20.8 | 57.4 | 75.6 | 94.5 | 60.2 | 98.2 | 43.8 | 46.0 | 36.8 | 24.2 | 23.0 | 21.0 | 1.90 | 72.9 | 174.9 |
| Jan. 27.. | 63.3 | 53.2 | 57.7 | 30.4 | 27.0 | 17.0 | 19.5 | 20.2 | 56.0 | 70.3 | 88.2 | 55.0 | 93.0 | 44.5 | 45.7 | 34.8 | 24.2 | 22.4 | 20.0 | 1.77 | 68.4 | 174.0 |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| THO. | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 5.. | 65.9 | 57.0 | 60.2 | 27.8 | 25.5 | 17.2 | 20.8 | 21.1 | 55.3 | 71.1 | 87.7 | 53.6 | 90.4 | 44.4 | 52.0 | 36.4 | 26.8 | 23.4 | 21.4 | 1.83 | 63.2 | 177.9 |
| Jan. 27.. | 65.5 | 56.8 | 61.5 | 27.0 | 25.0 | 17.0 | 20.8 | 20.8 | 55.0 | 69.0 | 84.4 | 50.4 | 88.5 | 44.0 | 51.4 | 35.0 | 26.7 | 23.1 | 20.3 | 1.77 | 59.9 | 177.5 |
| VAN. | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 5.. | 66.9 | 56.2 | 60.3 | 30.0 | 27.2 | 17.9 | 20.8 | 22.0 | 56.0 | 74.6 | 92.1 | 53.6 | 94.6 | 46.3 | 47.1 | 34.4 | 26.8 | 25.2 | 21.4 | 1.89 | 69.8 | 178.7 |
| Jan. 27.. | 67.4 | 55.8 | 62.5 | 28.0 | 26.2 | 17.0 | 20.2 | 21.6 | 58.5 | 71.2 | 88.7 | 50.3 | 91.2 | 46.2 | 47.0 | 34.0 | 27.0 | 23.9 | 21.0 | 1.85 | 65.4 | 178.4 |
| WIL. | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 5.. | 65.5 | 55.0 | 51.9 | 29.2 | 26.5 | 16.7 | 18.6 | 20.5 | 55.1 | 70.2 | 88.0 | 53.3 | 89.5 | 38.7 | 43.3 | 34.4 | 24.7 | 22.5 | 19.7 | 1.66 | 59.8 | 164.0 |
| Jan. 27.. | 64.5 | 54.5 | 52.0 | 28.0 | 25.5 | 15.7 | 18.5 | 19.5 | 53.5 | 67.0 | 82.5 | 49.5 | 86.5 | 41.0 | 43.5 | 33.0 | 24.5 | 21.4 | 19.2 | 1.58 | 57.1 | 164.0 |

TABLE 15.—*Body-surface measurements (Du Bois) for Fre, Lon, and McM.*

| Subject and date. | A | B | F | G | H | I | J | K | L | M | N | P | Q | W | R | S | T | U | V | Area computed from formula. | Body-weight without clothing. | Height. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FRE. | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *sq. m.* | *kg.* | *cm.* |
| Sept. 29.. | 66.7 | 56.2 | 58.0 | 29.1 | 25.6 | 15.5 | 20.2 | 20.2 | 53.7 | 68.7 | 87.4 | 49.0 | 83.3 | 43.9 | 43.9 | 33.3 | 24.5 | 21.8 | 19.3 | 1.67 | 57.5 | 167.1 |
| LON. | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 27.. | 67.1 | 54.2 | 60.0 | 28.5 | 26.3 | 17.2 | 21.4 | 21.0 | 57.8 | 66.8 | 91.8 | 49.4 | 88.0 | 43.0 | 49.5 | 34.0 | 25.7 | 22.5 | 20.0 | 1.80 | 63.8 | 178.4 |
| McM. | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 5.. | 66.5 | 57.0 | 55.5 | 31.2 | 27.5 | 17.2 | 18.5 | 21.2 | 56.0 | 76.3 | 86.4 | 55.2 | 95.1 | 42.0 | 44.8 | 34.8 | 26.0 | 22.0 | 22.8 | 1.79 | 68.8 | 169.8 |

TABLE 16.—*Du Bois linear formula to determine surface area.*

Subject, Kenneth B. Canfield. Date, Sept. 29, 1917.
Nude weight (kg.), 79.75. Height (cm.), 176.9.
Surface area (sq. m.), linear formula, 2.03; height-weight chart, 1.97.

| | Cm. | Log. | Sq. cm. |
|---|---|---|---|
| Head.................................. 0.308 | | 48855 | Head 1,162 |
| AB 0.308 — A Around vertex and chin....... | 66.8 | 82478 | Arms 2,894 |
| B Occiput and forehead.......... | 56.5 | 75205 | Hands 1,030 |
| | | | Trunk 7,694 |
| | | 06538 | Thighs 3,689 |
| | | | Legs 2,540 |
| Arms.................................. 0.611 | | 78604 | Feet 1,329 |
| F (G+H+I) 0.611 — F Acromium process to lower border radius............ | 59.2 | 77232 | 20,338 |
| G Circumference at axilla..33.2 | | | =2.034 sq. m. |
| H Largest of forearm......28.4 | 80.0 | 90309 | |
| I Smallest of forearm......18.4 | | | |
| | | 46145 | |
| Hands.................................. 2.22 | | 34635 | |
| JK 2.22 — J Radius to tip second finger.... | 20.9 | 32015 | |
| K Circumference hand at knuckles | 22.2 | 34635 | |
| | | 01285 | |
| Trunk.................................. 0.703 | | 84696 | |
| L (M+N) — L Suprasternal notch to pubes... | 60.4 | 78104 | |
| 0.703 — M Circumference at umbilicus............ 86.5 | 181.2 | 25816 | |
| N Circumference at nipples 94.7 | | | |
| | | 88616 | |
| Thighs.................................. 0.552 | | 74194 | |
| W (P+Q) — W Superior border pubes to lower border patella............ | 42.0 | 62325 | |
| 0.552 — P Circumference at perineum.............. 60.1 | 159.1 | 20167 | |
| Q Circumference hips and buttocks........... 99.0 | | | |
| | | 56686 | |
| Legs.................................. 1.40 | | 14613 | |
| RS 1.40 — R Sole of foot to lower border patella.................... | 49.7 | 69636 | |
| S Circumference at lower border patella.................... | 36.5 | 56229 | |
| | | 40478 | |
| Feet.................................. 1.04 | | 01703 | |
| T (U+V) — T Length of foot.............. | 26.9 | 42975 | |
| 1.04 — U Circumference base fifth toe................ 24.0 | 47.5 | 67669 | |
| V Smallest circumference ankle.............. 23.5 | | | |
| | | 12347 | |

ject was fairly thin at the beginning of the study. The minimum is again found with *Pec*, *i. e.*, 3.2 cm., while the average loss for the whole group is 5.1 cm.

The maximum loss for *P*, the girth at the perineum, occurred with *Spe*, 6.7 cm., while the minimum is with *Gul*, 2.6 cm. The average for the group is 4.6 cm. The largest loss in the circumference at the hips and buttocks, *Q*, is again found with *Spe*, with a decrease of 6.0 cm., and the minimum with *Tom*, with a loss of 2.5 cm. The average for the group is 4.3 cm.

When averaged somewhat arbitrarily, the losses in the five main circumferences for the whole group show a maximum loss with *Spe* of 6.2 cm., followed closely by *Can*, with 5.8 cm., with a minimum for *Pec*, the highly trained athlete, of 3.6 cm. The average for the group is 4.4 cm.

While in general many of the measurements show decreases roughly approximate to the percentage loss in body-weight, in certain instances the decrease is quite contrary to the percentage loss in body-weight. This is particularly true of the measurement *N* with *Tom*, this subject showing a larger decrease in this measurement than any other subject, although he had the smallest body-weight and his percentage loss in body-weight was the smallest. From a general inspection of the data no striking uniformity appears. Apparently no simple mathematical relationship between the decreases in girth and either the total loss or the percentage loss in body-weight may be established.

The period of loss in weight for Squad B was approximately 21 days. The losses in weight and in the five major girths during this period with these subjects are also given in table 17, together with the initial body-weight and percentage loss in weight. While a direct comparison of these losses is hardly justifiable, since the men were not of the same general contour, yet it is evident that the decreases are less than those found for Squad A. The final percentage loss in body-weight for this squad was but 6.5 per cent, as compared with 10.7 per cent with Squad A. If we take as a general index of decrease in these measurements the averages of the values for *G*, *M*, *N*, *P*, and *Q*, we find that they range from a maximum of 5.3 cm. with *Liv*, to a minimum of 2.3 cm. for *Tho*, the average for the whole group being 3.4 cm. This is perceptibly smaller than the average for Squad A, which was 4.4 cm.

The degree of emaciation produced by the restriction in diet may also be shown to some extent by means of the profile photographs given in figures 74 to 85. These were taken of the men in Squad A at the end of the experiment, *i. e.*, on February 2, 1918. For comparison, a photograph is also given of one subject (*Can*) which was taken on September 29, before the restriction in diet began. A loss in weight of 10 per cent or even, as with *Can*, 13 per cent, does not of

course, produce an effect which is especially evident. We believe, however, that photographic records of this type are important, particularly for hospital cases, and are strongly to be recommended. In reduction cures for obesity, particularly, such photographs might be of specific value.

In addition to the profile photographs, a group photograph was taken of Squad A in November, when they had nearly reached their minimum weight. This group photograph, which is reproduced in figure 86, was taken on the lawn near the Laboratory and gives a good indication of the appearance of the men at that period of the research. Knowing that these men are on a reduced diet, one may perhaps discern the evidence of emaciation, with possibly a drawn look in the face, but had these men been in company with other college men on the campus, it would have been very difficult for any one to have selected them as members of the diet squad without previous knowledge of that fact. In other words, these men were not greatly dissimilar in appearance from their fellow students. Another group photograph was taken on January 11, 1918, in which not only Squad A but also Squad B and the investigators were included. (See frontispiece.) On this date Squad B had been but 3 days on a reduced diet, and hence were practically in a normal condition.

## BODY-SURFACE.

The body-surface of the men in Squads A and B has been computed both from the photographs and from the Du Bois measurements. Finally, for further comparison we have drawn off the predicted surface areas from the height-weight chart. These values are given in tables 18 and 19. The method of computing the body-surface from

TABLE 18.—*Body-surface measured by different methods—Squad A.*

| Subject. | Du Bois linear formula. | | | Du Bois height-weight chart. | | | Photographic (5.02 C.). | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sept. 29. | Nov. 24. | Feb. 2. | Sept. 29. | Nov. 24. | Feb. 2. | Sept. 29. | Nov. 24. | Feb. 2. |
| | *sq. m.* | *sq. m.* | *sq. m.* | *sq. m.* | *sq. m.* | *sq. m.* | *sq. m.* | *sq. m.* | *sq. m.* |
| Bro | 1.69 | 1.62 | 1.61 | 1.70 | 1.61 | 1.62 | 1.71 | 1.58 | 1.55 |
| Can | 2.03 | 1.87 | 1.86 | 1.97 | 1.87 | 1.87 | 1.99 | 1.83 | 1.87 |
| Kon[1] | 1.83 | 1.75 | 1.72 | 1.78 | 1.74 | 1.71 | 1.80 | 1.80 | 1.69 |
| Gar | 1.86 | 1.74 | 1.74 | 1.83 | 1.76 | 1.75 | 1.91 | 1.79 | 1.73 |
| Gul | 1.81 | 1.71 | 1.72 | 1.75 | 1.67 | 1.69 | 1.76 | 1.66 | 1.63 |
| Mon | 1.88 | 1.76 | 1.78 | 1.81 | 1.72 | 1.72 | 1.84 | 1.74 | 1.72 |
| Moy | 1.79 | 1.70 | 1.68 | 1.77 | 1.69 | 1.71 | 1.80 | 1.72 | 1.66 |
| Pea | 1.88 | 1.74 | 1.76 | 1.79 | 1.72 | 1.72 | 1.88 | 1.79 | 1.69 |
| Pec | 1.84 | 1.74 | 1.74 | 1.75 | 1.70 | 1.70 | 1.79 | 1.76 | 1.66 |
| Spe | 1.79 | 1.67 | .... | 1.75 | 1.66 | .... | 1.78 | 1.66 | .... |
| Tom | 1.79 | 1.69 | 1.67 | 1.73 | 1.69 | 1.69 | 1.76 | 1.66 | 1.61 |
| Vea | 1.84 | 1.72 | 1.75 | 1.80 | 1.73 | 1.72 | 1.89 | 1.69 | 1.68 |

[1]The first body-surface measurements with *Kon* were obtained October 27.

TABLE 19.—*Body-surface measured by different methods—Squad B.*

| Subject. | Du Bois linear formula. | | Du Bois height-weight chart. | | Photographic (5.02 C.). | |
|---|---|---|---|---|---|---|
| | Jan. 5. | Jan. 27. | Jan. 5. | Jan. 27. | Jan. 5. | Jan. 27. |
| | *sq. m.* | *sq. m.* | *sq. m.* | *sq. m.* | *sq. m.* | *sq. m.* |
| Fis....... | 1.93 | 1.85 | 1.92 | 1.88 | 1.91 | 1.79 |
| Har...... | 1.83 | 1.75 | 1.77 | 1.72 | 1.75 | 1.66 |
| How...... | 1.95 | 1.85 | 1.89 | 1.83 | 1.88 | 1.77 |
| Ham..... | 1.97 | 1.94 | 1.96 | 1.92 | 1.89 | 1.89 |
| Kim...... | 1.78 | 1.70 | 1.76 | 1.75 | 1.78 | 1.65 |
| Sch....... | 1.84 | 1.78 | 1.77 | 1.71 | 1.75 | 1.71 |
| Liv....... | 1.71 | 1.61 | 1.67 | 1.62 | 1.71 | 1.65 |
| Sne....... | 1.90 | 1.77 | 1.88 | 1.82 | 1.82 | 1.77 |
| Tho...... | 1.83 | 1.77 | 1.79 | 1.75 | 1.75 | 1.70 |
| Van...... | 1.89 | 1.85 | 1.88 | 1.82 | 1.83 | 1.77 |
| Wil....... | 1.66 | 1.58 | 1.65 | 1.62 | 1.58 | 1.59 |

the Du Bois measurements, also the factors used in the linear formula are shown in the typical series of measurements given in table 16. The method of computing the body-surfaces from the profile photographs is as follows:

From an extensive series of photographs and measurements of men and women it was found that when the planimetered area of a photograph giving a profile view of a subject with left arm extended[1] was referred to a photographed meter scale, its relation to the total area of the body was represented by the average factor 5.02. In other words, the area of the planimetered section referred to the meter scale, when multiplied by 5.02, gave the total area of the body as computed by the Du Bois formula. Usually in planimetering, the photograph is divided into two approximately equal parts by an arbitrarily drawn line passing through the hips. The upper and lower sections are then planimetered separately and the sum of the two areas, which on our instrument is expressed in square inches, is multiplied by the factor 6.45 for conversion to square centimeters. The length of the meter scale in the photograph is then found in millimeters and the true area of the surface shown in the photograph obtained by a simple proportion. Thus, using the photograph of Greyson C. Gardner (*Gar*, fig. 78) as an illustration, we found that the lower part of the body gave an area by planimetering of 1.78 square inches and for the upper part of 2.31 square inches, the total area of the photograph being 4.09 square inches. This, reduced to square centimeters by means of the factor 6.45, gave a total area for the photograph of 26.4 sq. cm., or 0.00264 sq. meter. The meter scale in the photograph measured 87.5 mm. or 0.0875 m. The proportion used for calculating the actual surface of the body shown in the photographs

[1] Our so-called "pose C." See Benedict, Am. Journ. Physiol., 1916, 41, p. 275.

would therefore be: $l^2:1^2::a:x$, $l$ representing the length of the metric scale as photographed (0.0875 meter), $a$ the area of the photograph expressed in square meters (0.00264 square meter), and $x$ the actual surface area of the section of the body shown in the photograph. The general equation would be: $x=\frac{a}{l^2}$. The actual surface area of the section of *Gar's* body shown in the photograph would thus be 0.00264 sq. meter divided by 0.00765 or 0.345 sq. meter. Using the factor 5.02, which represents the relationship found to exist between the surface of the body shown in pose *C* and the surface of the whole body, we find that the body-surface of this subject as computed from the silhouette photograph is 1.73 sq. meters.[1]

With Squad A in September, when the first measurement was obtained, the surface areas as computed by the Du Bois formula are almost invariably higher than those found by the height-weight chart, while in November, at the time of the minimum weight, these differences practically disappear. We are somewhat at a loss to understand why there should be this variation, for the measurements were made with great care, although admittedly under considerable tension. The discrepancies are, however, not very great, but singularly enough lie almost invariably in one direction. When the values computed from the Du Bois formula from the set of measurements made on February 2 are compared with those calculated from the height-weight chart, we find a very close agreement for practically all of the subjects. The widest discrepancy is that with *Mon*, the values being 1.78 sq. meters for the Du Bois formula as compared with 1.72 sq. meters found with the height-weight chart. It is further noticeable that the differences are plus or minus, that is, the averages of the two areas for the squad as a whole would be nearly the same, irrespective of whether it was determined by the Du Bois linear formula or by the height-weight chart.

With Squad B a comparison between the results obtained with the Du Bois linear formula and the height-weight chart shows, for the most part, excellent agreement. For the measurements taken January 5, *i. e.*, before weight-reduction, the widest difference is found with *Sch*, the values being 1.84 sq. meters for the Du Bois formula as against 1.77 sq. meters for the height-weight chart. With the measurements taken after the reduction in weight (January 27), there is likewise fairly uniform agreement between the results obtained on the two bases of measurement. *Sch* again shows the greatest discrepancy, with 1.78 sq. meters for the Du Bois formula, as opposed to 1.71 sq. meters for the height-weight chart. In these later comparisons, how-

[1] Reference to the original description of the photographic method (Benedict, Am. Journ. Physiol., 1916, 41, p. 275) should be made for the technique of taking these photographs and other details of this method of calculating the surface area.

ever, the variations are plus or minus, leaving no difference between the average areas for the whole squad when measured by either method, while on January 5 there was a tendency, as with Squad A at the beginning of the experiment, for the linear formula to give slightly higher values than with the height-weight chart.

Comparing the areas for Squad A, as obtained by the photographic method, with those computed from the Du Bois measurements, we find that there are minor variations, but that on the whole the averages of the three measurements show that the total areas as determined by the three methods are essentially alike. The averages for Squad A for September 29 are 1.84, 1.79, and 1.83 sq. meters, for the Du Bois formula, height-weight chart, and photographic method, respectively. On November 24, the averages are 1.73, 1.71, and 1.72, respectively. On February 2 the areas computed from the photographs are in most instances smaller than they are by the linear formula, the widest difference being with *Gul*, 1.72 against 1.63 sq. meters, or 0.09 sq. meter. The average areas for the three methods are 1.73, 1.72 ,and 1.68 sq. meters, respectively.

With Squad B the area computed from the photographic method on January 5 is, in almost every instance, somewhat lower than that obtained by the linear formula, the widest difference being with *Sch*, 1.84 sq. meters as against 1.75 sq. meters. The averages are 1.84, 1.81, and 1.79 sq. meters. On January 27 a comparison of the two methods likewise shows somewhat lower values with the photographic method than with the Du Bois method. The averages for the three methods are 1.77, 1.77, and 1.72 sq. meters.

In addition to the 23 subjects given in tables 18 and 19, a single series of measurements was made with three other subjects, and the body surface obtained by the three methods. These were *Fre*, on September 29, 1917, *McM* on January 5, and *Lon* on January 27, 1918. The values for these three subjects are given in table 20 as supplementary evidence. These values show essentially the same picture as those for the larger group of 23 men.

TABLE 20.—*Body-surface measurements, supplementary data.*

| Subject. | Date. | Du Bois linear formula. | Height-weight chart. | Photographic (5.02C.) |
|---|---|---|---|---|
| Squad A: | | *sq. m.* | *sq. m.* | *sq. m.* |
| Fre.... | Sept. 29, 1917... | 1.67 | 1.64 | 1.65 |
| Squad B: | | | | |
| McM.. | Jan. 5, 1918..... | 1.79 | 1.80 | 1.73 |
| Lon... | Jan. 27, 1918.... | 1.80 | 1.80 | 1.75 |

We may, perhaps, make the best comparison of the two methods by computing the factor to be used in the photographic method for each

ments of the respiratory exchange, the oral temperature of the subject was taken with a standard clinical thermometer. These records were made simply to eliminate the possibility of measuring the gaseous exchange when the subject was in a slightly febrile or febrile condition, and not with a view to determining the physiological temperature, for as is well known, mouth temperatures have no definite physiological value.

Throughout the entire series abnormal temperatures were rarely found. Occasionally slightly febrile temperatures were noted when the subject was suffering from a cold; under these conditions the gaseous metabolism was not measured. With *Spe* abnormal body temperatures were recorded for a number of days prior to his leaving for home in consequence of suspected typhoid infection.

### RECTAL TEMPERATURE MEASUREMENTS.

In contrast to the temperature measurements taken in the mouth, the temperature measurements made in the rectum were of true physiological significance. These were obtained at the end of the night experiments with the respiration chamber in Boston and just before the subject arose in the morning. For this purpose 12 accurate clinical thermometers were used; all of these thermometers had previously been carefully calibrated with a standard Richter thermometer. Owing to the darkness of the chamber it was impossible for the experimenters to insert the thermometer personally. After the bulbs of the thermometers had been coated with vaseline, each man was instructed to insert a thermometer more than half its length in the rectum. Inasmuch as the men were an unusually intelligent group and thoroughly appreciative of the importance of the experiment, we have reason to believe that the thermometers were in all instances satisfactorily inserted and that the temperature recorded may be taken as a true measure of the rectal temperature of these men. After the thermometers had been removed they were carefully read and checked by a second person before the records were finally made.

The special advantages of taking rectal temperatures under these conditions were, first, that the subjects had all received a constant standard meal at 5 p. m. the night before. Furthermore, they were lying on the beds inside the chamber for not less than 7 to 8 hours prior to the temperature record; during this time the environmental temperature was almost absolutely constant, and, except in very rare cases, the subject slept the entire night. Finally, as stated above, the temperatures were taken the first thing in the morning, before activity of any kind was engaged in. The conditions thus seemed to be ideal for obtaining true records of the rectal temperature. As with a number of our observations, the records of the rectal temperature under these conditions were not begun until November 11; hence

the rectal temperatures of Squad A prior to diet reduction were not secured.

The rectal temperatures obtained for Squad A throughout the entire series are given in table 21. From this it is seen that the only record of a really abnormal temperature was that for *Kon* on December 9. *Gar*, on November 25, had a slight rise in temperature which, after his return to Springfield, was followed by another rise in temperature due to a cold. The inspection of these figures shows that the temperatures were practically all within so-called "normal" limits. It should be observed, however, that the group averages are not strictly comparable. Thus, on all measurements subsequent to December 9, *Spe* was missing. On January 13 *Tom* was likewise missing, and on January 27, owing to the fact that *Tom* had had an operation for hemorrhoids, the axillary temperature alone could be obtained.

TABLE 21.—*Rectal temperatures during period with reduced diet*[1]*—Squad A.*
[Subjects post-absorptive and in lying position.]

| Subject. | Nov. 11. | Nov. 25. | Dec. 9. | Dec. 20. | Jan. 13. | Jan. 27. | Feb. 3. |
|---|---|---|---|---|---|---|---|
| | °F. | °F. | °F. | °F. | °F. | °F. | °F. |
| Bro........ | 97.6 | 97.4 | 97.2 | 97.0 | 96.7 | 97.1 | 97.6 |
| Can........ | 97.7 | 97.6 | 97.7 | 98.2 | 97.7 | 97.6 | 97.8 |
| Kon........ | 97.9 | 97.9 | 100.2 | 97.3 | 97.9 | 97.7 | 99.0 |
| Gar........ | 96.6 | 99.0 | 96.3 | 96.9 | 96.8 | 95.8 | 96.0 |
| Gul........ | 97.1 | 96.5 | 97.7 | 97.1 | 97.1 | 97.0 | 97.3 |
| Mon........ | 98.4 | 97.8 | 98.5 | 98.8 | 97.7 | 98.2 | 98.7 |
| Moy........ | 98.0 | 97.1 | 97.5 | 97.4 | 97.2 | 96.8 | 97.1 |
| Pea........ | 97.5 | 96.8 | 97.4 | 97.2 | 97.1 | 97.1 | 96.6 |
| Pec........ | 98.1 | 97.9 | 98.5 | 98.0 | 97.2 | 97.1 | 97.2 |
| Spe........ | 97.4 | 97.5 | 97.6 | .... | .... | .... | .... |
| Tom........ | 96.8 | 97.1 | 97.3 | 96.7 | .... | [2]96.3 | 97.2 |
| Vea........ | 98.2 | 97.5 | 97.9 | 98.0 | 97.6 | 98.0 | 97.4 |
| Average.... | 97.6 | 97.5 | 97.8 | 97.5 | 97.3 | 97.2 | 97.4 |

[1] Observations were made early in the morning after a night in the group respiration chamber. The last preceding meal was the standard supper (700 cals.) served at the restaurant.
[2] Taken in axilla; not included in average.

On the other hand, actual computations show that the changes in temperature of the individuals were so slight that excluding one or two men does not materially alter the general average for the temperature measurement. The average values for the complete series ranged from the maximum of 97.8° F. on December 9 to a minimum of 97.2° F. on January 27.

Under these conditions it is clear that the average rectal temperature of Squad A from November 11 to February 3, inclusive, can not be said to have undergone measurable change. An examination of the data for different individuals shows likewise no tendency for a distinct alteration in temperature, and we must conclude that the

effect of the reduced diet upon these men is without influence upon the rectal temperature taken under the conditions observed in these tests.

It would be conceivable that with Squad A a perceptible fall in temperature might take place in the first month of the diet reduction. This of course would not be shown by our values, as we had no records of the normal temperatures previous to the reduction in food. With Squad B, however, a sufficient number of rectal temperatures were recorded prior to the diet reduction to give a suitable base line. The records for Squad B are given in table 22. Here the situation is complicated by the fact that occasionally the individual members of the squad were changed for reasons beyond our control, but this, we believe, has no effect upon the general averages.

TABLE 22.—*Rectal temperatures of Squad B.*[1]

[Subjects post-absorptive and in lying position.]

| Subject. | Normal diet. | | | Reduced diet. | | |
|---|---|---|---|---|---|---|
| | Nov. 18. | Dec. 16. | Jan. 6. | Jan. 14. | Jan. 20. | Jan. 28. |
| | °F. | °F. | °F. | °F. | °F. | °F. |
| Fis....... | 97.2 | (2) | 96.9 | 96.7 | 96.9 | 96.5 |
| Har...... | 98.3 | 97.7 | 98.7 | 97.9 | 97.7 | 96.9 |
| How...... | 97.9 | 97.7 | 97.6 | 97.5 | 97.2 | 97.3 |
| Ham..... | 97.4 | 97.5 | 97.6 | 97.4 | 97.2 | 96.9 |
| Kim...... | (3) | (3) | 98.3 | 96.6 | 97.1 | 97.1 |
| Lon...... | 98.4 | 98.5 | (4) | 98.6 | 97.3 | 96.6 |
| Sch....... | (5) | (5) | 97.2 | 97.4 | 97.5 | 96.6 |
| Liv....... | 97.9 | 97.0 | 97.9 | 97.7 | 97.0 | 97.1 |
| Sne....... | 98.3 | 97.7 | 97.0 | 97.8 | 97.4 | 97.1 |
| Tho...... | 98.4 | 98.5 | 98.8 | 97.9 | 97.3 | 96.9 |
| Van...... | 97.5 | 97.2 | 97.0 | 97.1 | 96.9 | 96.2 |
| Wil....... | 97.3 | 97.4 | 97.7 | 96.7 | 96.9 | 96.2 |
| Average .. | 97.9 | 97.7 | 97.7 | 97.4 | 97.2 | 96.8 |

[1] Observations were made early in the morning after a night in the group respiration chamber. The last preceding meal was the standard supper (700 cals.) served at the restaurant

[2] Leo substituted for Fis, Dec. 16; rectal temperature, 97.6° F.

[3] McM substituted for Kim; rectal temperature, Nov. 18, 98.5° F.; Dec. 16, 98.1° F.

[4] McM substituted for Lon, Jan. 6; rectal temperature, 98.1° F.

[5] McD substituted for Sch; rectal temperature, Nov. 18, 98.2° F.; Dec. 16, 97.5° F.

Prior to the diet reduction the values for Squad B on November 18, December 16, and January 6 show averages of 97.9°, 97.7°, and 97.7° F., respectively. In other words, the rectal temperature can be said with this squad of 12 men to be constant. Subsequent to the change in diet there is, in rather striking contrast to the values found with Squad A, a distinct tendency for the rectal temperature to fall. Thus, on January 14, approximately one week after the reduced diet began, the average temperature was 97.4° F., at the end of two weeks, 97.2° F., and at

too small for best deductions. The measurement of skin temperature was admittedly an afterthought. The results are, however, extensive to warrant presentation, if the paucity of normals The values obtained for Squads A and B are given in table 23.

TABLE 23.—*Skin temperatures of Squads A and B during periods of reduced diet.*

[1] Room temperature, Jan. 26, 22.8° C.
[2] Room temperature, Feb. 2, 25.2° C.
[3] Room temperature, Jan. 19, 23.6° C.
[4] Room temperature, Jan. 27, 27.3° C.

The first series of skin temperature measurements was made with Squad B on January 19, when the men had been two weeks on the reduced diet. The subjects had been sitting in the library taking the group psychological tests for approximately an hour prior to the temperature measurements, and had engaged in no physical exercise. At the end of these group psychological tests the men were instructed to place their hands, palms down, upon the table and remain quiet while the observations on skin temperature were being recorded. The room temperature, as taken by a thermometer suspended at approximately the level of their heads, indicated 23.6° C. on this particular date. The results of the temperature measurements upon the surface of the upper side of the right and left hands and on the forehead are given for all of the men in Squad B, together with the measurements for two individuals on unrestricted diet. Subsequent observations of the temperature of the forehead have shown that this location gives by far the best measurement of the skin temperature, with less fluctuation, than any other part measured.

Measurements were made upon the backs of both the right and left hands to find if the unilateral disturbance suggested in some of the protocols and subjective impressions of some of the men was actually present. An inspection of the values for Squad B on January 19, shows that there is relatively little difference between the temperatures for the two hands. In only three cases (*How*, *Van*, and *Wil*) were there differences greater than 1.5° C. That this difference is not characteristic of these men can be seen from subsequent values found on January 27, on which date the temperatures for both hands were much more nearly constant.

Comparing the values for Squad B on January 19 with those for two normals on the same date, we find that for the right hand the average temperature is for the 12 men 31.34° C., while the record for each of the normals is somewhat less than this. With the left hand the average temperature for Squad B is 30.95° C.; both of the normals show temperatures somewhat lower. These results would indicate that the average temperature of the hands with Squad B was slightly higher than the temperature measurements obtained for the two normals. It should be stated, furthermore, that both normals had been moderately occupied in giving the psychological tests during the previous hour, which involved considerably more exercise than had been taken by Squad B.

The temperature of the forehead ranged with Squad B from 31.93° C. (*Wil*) to 34.1° C. (*Kim*). The average for the 12 men is 32.7° C. The two normals, however, show perceptibly higher forehead temperatures, namely, 33.63° C. and 34.23° C.

Subsequent research has shown the rather striking influence of changes in room temperature upon the temperature of the skin.

in the Nutrition Laboratory and by Professor Johnson in Springfield, unfortunately our temperature measurements were not made for the purpose of determining the reaction of the temperature regulating function to muscular work. *Pea* was captain of the cross-country team, and on several occasions ran a strenuous race. On November 28 he ran a race of 6¾ miles according to the pedometer record. It was impracticable to measure his rectal body temperature under these conditions, but the mouth temperatures are perhaps not without some interest. At $9^h30^m$ a. m. after breakfast, when he was lying down, the mouth temperature was 98.6° F. After a run of 54 minutes of approximately 7 miles, and while the subject was lying on the bed, the mouth temperature at $11^h18^m$ a. m. was 97.4° F. The fact that this subject had been running a race in the open air, with probably more or less mouth breathing, makes these records of relatively little value. The difficulties in obtaining accurate records of the mouth temperature, especially after long races, have been carefully pointed out by Dr. Blake in his observations on Marathon runners.[1] It is more than probable, however, that there was no true increase in temperature as a result of this activity, for this fall of 1.2° F. is not unlike that recorded by Blake and his co-workers in the case of the Marathon runners.

### CONCLUSIONS REGARDING EFFECT OF DIET ON BODY TEMPERATURE.

Practically all that can be said regarding these records of body temperature is that the reduced diet did not, save in the case of Squad B, produce any noticeable alteration from the ordinary temperature control exhibited by normal individuals. The febrile temperature of *Spe* has been a matter of very considerable perplexity. On December 9, at 6 a. m., in the respiration chamber in Boston, this subject gave a rectal temperature of 97.6° F. On December 12 at $5^h45^m$ a. m., prior to the gaseous-metabolism experiment, he had a mouth temperature of 99.6° F. On December 13 records of the mouth temperature were taken very frequently. In the morning it was 100.5° F.; later in the afternoon the attending physician recorded it as 102° F.; at $6^h30^m$ p. m., 102.5° F.; at 7 a. m., December 14, 102.2° F.; at 6 p. m., December 14, 104.2° F.; and in the early morning of December 15, 102.8° F. *Spe* then left Springfield for his home. The body-temperature record in the subsequent course of the illness is given in figure 87 on page 363. The variations in the temperature curve of typhoid patients are altogether too wide to allow any deductions as to whether this case of suspected typhoid showed usual values or not. It is clear, however, that no extraordinarily high or low temperature measurements were found even in this case of infection, and that the important temperature-regulating function of the body is capable of

[1] Blake and Larrabee, Boston Med. and Surg. Journ., 1903, **148**, p. 195.

withstanding very material alterations in the diet without noticeable disturbance.

In the recent study made by Loewy and Zuntz,[1] the latter found no change in his body temperature at the end of his experiments on low diet, the values obtained in 1916 being no lower than those recorded prior to the war. No temperature measurements for Loewy are reported.

## DIFFICULTIES IN TEMPERATURE REGULATION AS INDICATED BY CLOTHING.

A noticeable feature of the experiment, which became evident about the middle of November and was more pronounced in the latter part of the research, was the extreme sensitivity of the subjects to cold.[2] The winter of 1917–18 was unusually severe, which may, in small part, have accounted for this increased sensitivity, but the evidence seems to be clear that the men on diet were actually more sensitive to cold than their college mates living under normal conditions.

This increased sensitivity to cold manifested itself in several ways:

(1) Nearly all of the men wore heavier underclothing than usual and were inclined to wear more overclothing.

(2) The bed clothing was frequently very noticeably increased.

(3) The men were also inclined to gather about the steam radiators whenever possible.

(4) They avoided swimming in the natatorium, although the water felt comfortably warm to their college mates.

As early as November 4, 1917, several of the men, especially *Pec*, *Can*, and *Pea*, complained of being cold during the morning respiration experiments. Although the temperature of the room was normal, they asked for additional blankets, and *Pea* had changed to heavy winter underwear on the day previous on account of the cold. After the excess diet on the uncontrolled Sundays, it was not infrequently reported by the subjects that they felt much warmer and more comfortable than on the days when the diet was restricted.

December 6, *Can*, *Tom*, and *Pec* complained of the cold hands of the assistant who was taking the pulse-rate. At the Nutrition Laboratory, although the halls were sufficiently warm for persons wearing ordinary clothing, it was noted that when the later series of profile photographs was taken with Squad A, gooseflesh appeared almost immediately when the subject removed his bath wrap. This did not occur with Squad B. On reaching the Laboratory when they came to Boston, the members of Squad A would gather around the radiators and apparently take this time to get warm.

On February 2 (the experiment ended on February 3) each member of the squad was questioned particularly with regard to clothing worn during the experiment. Their comments follow:

*Pea* reported that during his 3 years in college he had always worn light underwear through the winter and did not feel the cold. During the

[1] Loewy and Zuntz, Berl. klin. Wochenschr., 1916, 53, p. 829.

[2] Increased sensitivity to cold was experienced by the fasting subject. (Benedict, Carnegie Inst. Wash., Pub. No. 203, 1915, p. 194.)

winter of 1917–18 he had to wear heavy all-wool underwear. He noticed his feet and hands were particularly cold. His roommate, who was not a member of Squad A, wore light underwear as usual.

*Gar* had worn light underwear during the winter for 4 or 5 years. During that time he had not noticed the cold particularly. During the winter of 1917–18 he wore medium-weight union suits, half wool and half cotton, with full-length sleeves and ankle-length legs. His roommate, who was not on the squad, wore no heavier underwear than usual.

*Gul* stated that he had worn no underwear since the experiment began. He found it especially difficult to reduce his weight 10 per cent, and believed that if he wore no underwear the radiation of heat would be more rapid. Usually he wore light underwear in the summer and heavy underwear in the winter. During the intense cold of 1917–18 his shins felt very cold when the wind came in between his socks and trousers. When he first came to Massachusetts from North Dakota, a few years before, he did not feel the cold, because the winters in North Dakota are more severe than in Massachusetts. He thought he had not suffered from the cold more during the experiment than in the preceding winter. He wore underwear during the previous winter and had had two colds, the cause for which was not evident. During the winter of 1917–18 he had had no colds. It is a surprising fact that although the other subjects showed great sensitiveness to cold, this man was able to wear absolutely no underwear during the unusually severe winter and with a low diet. This is in striking contrast to the experience of practically all of the other members of the squad.

*Vea*, for the previous 4 years, had worn light underwear throughout the whole winter. During the winter of 1917–18 he wore cotton and light-weight woolen underwear, with long sleeves and legs of ankle length. For his walks outdoors, he put on woolen socks. During the last two weeks of the experiment he wore a basket-ball shirt under his regular shirt, in addition to the underclothes. The overcoat worn during the winter was lighter than usual.

*Can* had usually worn two-piece light-weight underclothes, but during the experiment he wore a knitted sweater and heavier drawers and socks than ordinarily. At times he put extra blankets on the bed to keep warm at night.

*Tom*, although not actually suffering from the cold, had felt cold and found his tendency was to stay indoors more. He slept in his bath-robe many times and kept moving when out of doors. It was his usual habit to wear the same weight of clothing throughout the year, with the exception of an overcoat in winter. During the experiment he wore no heavier underclothing or socks than usual. His chief difficulty was in keeping warm at night. Although he used an extra pair of blankets, besides his bath-robe, he was unable to keep warm in bed.

*Pec* reported special difficulty in keeping warm. On going to bed he could not get to sleep for half an hour on account of the cold. He usually wore a union suit of medium weight, but during the winter of 1917–18 he wore the best and heaviest woolen underwear that he could buy. He also wore a very heavy sweater every day in addition to his regular clothing while in the class room and the heaviest woolen socks that he could purchase.

*Moy* dressed more warmly than usual. For the previous 5 years he had worn light underwear throughout the winter. In November, when the weather became colder, he felt cold and put on union suits, knee-length, with short sleeves and of medium weight, but not all wool; no heavier socks were used. In the extreme cold weather he wore a sleeveless basket-ball sweater over his underclothes a part of the time. He also put more blankets on his bed. His overcoat was heavier than that worn the preceding year.

*Kon* reported that he suffered from cold. He usually wore light weight underwear, but about the middle of November began to wear heavy union suits, with long sleeves and legs of ankle length, about two-thirds woolen. He also wore heavy woolen socks and a medium-weight overcoat.

*Mon* suffered from cold, also. He usually wore heavy cotton underclothes and stockings, but in 1917–18 found it necessary to wear wool during the winter and much heavier woolen stockings. Part of the time he wore a jersey sweater and a heavier overcoat than usual, with more blankets at night.

*Bro* wore, ordinarily, a regulation gymnasium suit as underwear, *i. e.*, a jersey and running costume. During the cold weather of 1917–18 he wore a two-piece fleece-lined suit, but not all wool. This was of medium weight, with long sleeves and legs of ankle length. An extra sweater was worn in gymnasium work. Additional blankets were used at night, but he found it difficult to keep warm. He did not open his window so wide as usual.

The experiment ended for Squad B on January 28 and for Squad A on February 3. On February 8 the men of both squads were interviewed. They showed great uniformity of experience in regard to feeling cold during the period of reduced diet. In general, the members of Squad B did not change to heavier underclothing, and only one or two mentioned heavier outer clothing. The comments of the men, which are given here in detail, show that the contrast between the diet condition and the subsequent period of uncontrolled eating is definite, even though at the time of the interviews but a few days had elapsed since the close of the experiment.

### SQUAD A.

*Bro* had not changed the weight of clothing, but considered doing so mmediately, as he did not feel the cold so much as during the experiment.

*Can* said cold was not felt so keenly as during the experiment. No change in clothing, except for removal of sweater a part of the time. Much more comfortable than when on low diet; sometimes a little too warm; no change in bedding.

*Kon* had no doubt as to there being a great difference regarding his sensitiveness to cold; wearing the same clothing.

*Gar* had put on light silk stockings, but still wore long underclothing. He had not felt the cold so much since returning to full diet, but the weather had not been so cold.

*Gul* felt warmer than when on low diet. Had not begun to wear underclothes again except a 6-ounce jersey. Intended to put on underclothes the next day.

*Mon* did not feel cold on full diet. No change in clothing or bedding.

*Moy* did not notice cold so much as when on low diet; no change in clothing or bedding; sometimes felt too warm.

*Pea* had taken off flannel drawers and flannel shirt and wearing only a light weight cotton union suit. No change in bedding, but weather not so cold; windows open as usual.

*Tom* did not mind the cold so much and found that he was warmer in bed than when on the diet. Had taken off two pairs of blankets even during a recent period of cold weather.

*Vea* very sure that the cold was not felt so keenly as during the experiment. No change in clothing or bedding.

## DIETS.

In any plan to provide a pronounced reduction in diet it is important to emphasize the character of the foods eaten as well as the amount of reduction. It should be stated at the outset that we hold no thesis for any particular types of food, dietetic peculiarities, or régime. Consequently we believed that the most logical method of studying this problem was to give the men, so far as the character of food was concerned, as great a variety as they would normally receive were they not on diet. Throughout the entire test, therefore, with but very few exceptions, the subjects received regular college mess-hall food. The exceptions were the substitution of grape or apple jelly for butter during certain periods of excessive reduction, and the addition of rather considerable amounts of spinach and bulky food materials that would not commonly be received in the diet. The food was well prepared and served at a special table, but undoubtedly the presence of others consuming liberal amounts of food was disturbing psychologically. The members of the squad frequently indicated that this was a true disturbance.

Since with Squad B the diet restriction amounted to practically two-thirds of the normal intake, that is, the normal intake of approximately 4,000 calories was reduced to approximately 1,500 calories, it became necessary to be sure that no vital food accessories or none of the unidentified dietary factors were omitted. Typical menus covering several days were therefore submitted to Dr. E. V. McCollum, of the Johns Hopkins University, who was kind enough to inspect them and reported that, in his judgment, there was no deficiency in unidentified dietary factors. One difficulty arose in that this reduced diet had a tendency to produce constipation in many cases. This was counteracted by a rather liberal use of bran. At first, admittedly too liberal use was made of the bran until it was realized that an appreciable proportion of the total daily calories was being supplied by this material. Subsequently the bran was used in moderation by practically all of the subjects. In addition, bran biscuits, bran muffins, and some patent bran preparations were used, which made it possible to control the constipation without much difficulty.

At the beginning of the test the Woods Hall dietary included butter; this was later replaced with nut margarine; finally, to reduce the caloric intake and still provide something to eat with bread, the subjects were given jelly as a substitute.

Since we had no predilection for either a high or low protein diet, we gave no attention to the nitrogen intake, at least at the beginning, but simply curtailed the caloric intake in general by serving one-half to one-third of the regular portions. Obviously this procedure automatically resulted in a curtailment of the nitrogen intake. But the fact should be emphasized that these diets were, so far as character is

concerned, changed but little from the ordinary diet. No special factors were missing and our subjects were served food exactly like that served the other college men, except that they were given smaller portions.

The quantities of food served were, in all instances, much smaller than the normal pre-diet food consumption. The total nitrogen and total energy available for the individual subjects are recorded in various tables in other sections of this book; special reference to these

TABLE 24.—*Typical day's diet during period of maintenance of body-weight. Squad A.*

| Kind of food (Dec. 12, 1917). | Amount. | Nitrogen. | Energy. |
|---|---|---|---|
| Breakfast: | *gms.* | *gms.* | *cals.* |
| Bran muffins | 75 | | |
| Milk (topped) | 350 | [1]2.75 | [1]485 |
| Prunes | 30 | | |
| Bran | 14 | .31 | 58 |
| Sugar | 15 | .......... | 59 |
| Butter | 10 | .02 | 76 |
| Shredded wheat | 58 | .99 | 233 |
| Total | .......... | 4.07 | 911 |
| Dinner: | | | |
| Beefsteak | 50 | | |
| Potato | 153 | | |
| Tomato | 50 | [1]4.41 | [1]653 |
| Gravy | 37 | | |
| Bran muffins | 100 | | |
| Cornstarch pudding | 78 | | |
| Jelly (currant) | 10 | .......... | 27 |
| Total | .......... | 4.41 | 680 |
| Supper: | | | |
| Bran muffins | 80 | | |
| Milk (topped) | 233 | | |
| Toast | 40 | | |
| Chipped beef | 20 | [1]4.35 | [1]892 |
| Cream sauce | 84 | | |
| Potato (fried) | 110 | | |
| Raspberry preserve | 42 | | |
| Cookies | 23 | | |
| Butter | 10 | .02 | 76 |
| Total | .......... | 4.37 | 968 |
| Total for day | .......... | 12.85 | 2559 |

[1] Determined; all other values computed.

will not be made until these tables are discussed. Examples of characteristic diets, with amounts served, are, however, of interest here, and we give in table 24 an illustration of a typical day's ration (December 12, 1917) for Squad A during a period of approximate weight maintenance. As will be seen, a large proportion of the diet was

included in the composite samples, as outlined on page 68, and such staples as bran, sugar, shredded wheat biscuit, and butter were not analyzed. The total nitrogen for the day was 12.85 grams and the total energy 2,559 calories. These values represent an average for the 12 men. Individual variations, of course, were somewhat wide. The energy in this table represents the actual heat of combustion, *i. e.*, the gross calories. The menu is given primarily as an indication of the character and amounts of the foods taken by the subjects during the period of approximate weight maintenance.

A few standard meals were regularly used throughout the entire series of tests. Thus, on the biweekly trips to Boston, the men had a standard supper at a local restaurant. This was given throughout the entire winter with but slight changes; repeated samplings of the supper showed practically uniform values for both nitrogen and heat of combustion. These are shown in table 25. The meal was

TABLE 25.—*Standard restaurant supper.*[1]

| Kind and amount of food. | Nitrogen. | Energy. |
|---|---|---|
| | *gms.* | *cals.* |
| 1 fried egg | | |
| 2 pieces bacon (about 15 gms.) | | |
| 1 boiled potato (medium size; about 115 gms.) | [2]2.36 | [2]631 |
| 1 dish cooked spinach (113 gms.) | | |
| Apple pie (4¼ oz. or 120 gms.) | | |
| ½ orange (about 80 gms..) | | |
| 1 pat butter (about 10 gms.) | .02 | 76 |
| Total | 2.38 | 707 |
| No drink except water. | | |
| Vinegar on table for spinach, if desired. No sugar or oil. | | |

[1] Lettuce was served instead of spinach until December 15. Squad A was given very weak tea with slice of lemon and 7 to 12 grams sugar beginning with December 19. On January 26 the amount of bacon was changed to 1 piece (about 8 grams).

[2] Determined in composite sample.

especially relished by the men, who frequently spoke of it on arriving at the Laboratory. It has special significance as an indication of the character and amount of the food material eaten by each member of both Squads A and B on the evenings prior to the psychological tests.

Similarly on Sunday morning, at the conclusion of the all-night respiration experiments, and just prior to the psychological observations, a standard breakfast was provided at the Nutrition Laboratory. This remained practically uniform throughout the entire period of observation. The menu for this meal is given in table 26. The total amount of nitrogen supplied in this case was 3.55 grams and the total energy 640 calories.

On a certain number of occasions the subjects came to Boston early enough in the day to take a dinner at the restaurant. No major

TABLE 26.—*Standard laboratory breakfast.*

| Kind and amount of food. | Nitrogen. | Energy. |
| --- | --- | --- |
| | *gms.* | *cals.* |
| 1 roll (36 gms.)<br>½ banana (50 gms.)<br>1 pint topped milk<br>1 shredded wheat biscuit (28 gms.)<br>Jelly (25 gms.)<br>Bran (15 gms.)<br>Sugar (10 gms) | [1]3.55 | [1]640 |

[1] Computed.

changes were made in this meal during the experimental period, although there were some substitutions owing to the differences in the regular bill of fare available on particular days, and some changes in the total amounts of nitrogen and energy. The menu is given in table 27. The footnotes to this table indicate the character of the changes made on the different days.

TABLE 27.—*Standard restaurant dinner.*[1]

| Kind and amount of food. | Nitrogen. | Energy. |
| --- | --- | --- |
| | *gms.* | *cals.* |
| 1 oz. roast lamb, free of fat (28 gms.)<br>1 boiled potato (about 150 gms.)<br>1 ladleful gravy<br>½ slice bread, white (12.5 gms.)<br>Squash pie (4 oz. or 113 gms.)<br>½ orange (about 80 gms.) | [2]3.48 | [2]546 |
| 1 pat butter (about 10 gms.) | .02 | 76 |
| Total | 3.50 | 622 |
| No drink except water. | | |

[1] Roast beef (large slice) was served instead of lamb on Nov. 10 and Nov. 24, a smaller potato (about 75 gms.) and a serving of cranberry jelly instead of butter, but of about the same size. On December 8 the roast beef was decreased to about 1 oz., the potato was increased to about 125 gms., and butter was served instead of jelly.
[2] Determined in composite sample.

On Sunday nights in Springfield it was the custom of the college for the men to separate more or less, and no regular evening meal was served. Beginning October 7, the men were assigned small lunches, which consisted at first of a cake of sweet chocolate, with some form of bran. Later the chocolate was omitted and fruit substituted or served alone. The Sunday night suppers, with their nitrogen and energy content, chiefly computed, are given in detail in table 28. Usually, particularly when fruit and bran muffins were given, they were included for analysis in the sample of the noon meal. With the bran preparations and chocolate, analyses of the individual materials

TABLE 28.—*Sunday suppers at Springfield.*

| Squad and date. | Kind of food. | Amount. | Nitrogen. | Energy. |
|---|---|---|---|---|
| Squad A: | | *gms.* | *gms.* | *cals.* |
| Oct. 7, 1917.... | Braneta......................... | 31 | 0.48 | 129 |
| | Baker's chocolate, sweet, 5-cent cake.. | 58 | .33 | 322 |
| | Total..................... | .......... | 0.81 | 451 |
| Oct. 21, 1917... | Braneta......................... | 27 | .42 | 113 |
| | Baker's chocolate, sweet, 5-cent cake.. | 58 | .33 | 322 |
| | Total..................... | .......... | .75 | 435 |
| Nov. 4, 1917... | Braneta......................... | 32 | .50 | 134 |
| | Baker's chocolate, sweet, 5-cent cake.. | 58 | .33 | 322 |
| | Total..................... | .......... | .83 | 456 |
| Nov. 18, 1917... | Bran muffins..................... | 50 | .49 | 118 |
| | Graham crackers.................. | 42 | .67 | 187 |
| | Baker's chocolate, sweet............ | 29 | .16 | 161 |
| | Total..................... | .......... | 1.32 | 466 |
| Dec. 16, 1917... | Apple, as purchased................ | 250 | 0.13 | 121 |
| Jan. 20, 1918... | Bran muffins..................... | 90 | 1.03 | 245 |
| | Apple, as purchased................ | 125 | .06 | 61 |
| | Total..................... | .......... | 1.09 | 306 |
| Jan. 27, 1918... | Apple, as purchased................ | 200 | 0.10 | 97 |
| Squad B: | | | | |
| Jan. 20, 1918... | Bran muffins..................... | 90 | 1.03 | 245 |
| | Apple, as purchased................ | 225 | .11 | 109 |
| | Total..................... | .......... | 1.14 | 354 |

made it possible to compute the nitrogen and energy as indicated in the table.

Squad B, which was put upon an extremely low ration during the month of January, received reasonably uniform calories throughout the entire period, averaging 1,375 net calories. A typical day's ration, that for January 25, is given in table 29. A composite sample was made of all three meals, excluding certain of the staples, such as jelly, sugar, orange, and bran. The nitrogen and energy, as computed from standard analyses, are likewise included in table 29 to show the general distribution among the various food materials and in the three meals. The actual determinations for the total nitrogen intake and total gross calories in the composite sample are given at the bottom of the table. These, with the computed nitrogen and energy in the staple foods, give a total for the day of 8.78 grams nitrogen and 1,555 gross calories.

TABLE 29.—*Typical day's ration during period of reduced diet, Squad B (Jan. 25, 1918).*

| Kind of food. | Amount. | Nitrogen. | Energy. |
|---|---|---|---|
| Breakfast: | *gms.* | *gms.* | *cals.* |
| Orange (1) | 160 | 0.21 | 86 |
| Shredded wheat | 30 | .51 | 121 |
| Milk (topped) | 233 | 1.04 | 102 |
| Toast | 25 | .38 | 78 |
| Sugar | 9 | .... | 36 |
| Jelly (grape) | 10 | .... | 26 |
| Bran | 12 | .32 | 50 |
| Total (computed) | .... | 2.46 | 499 |
| Dinner: | | | |
| Soup | 70 | .41 | 19 |
| Fish | 40 | 1.16 | 87 |
| Potato (riced) | 70 | .28 | 70 |
| White sauce | 37 | .17 | 54 |
| Corn (canned) | 44 | .20 | 46 |
| Bread ("war bran bread") | 50 | .95 | 175 |
| Ice cream | 67 | .29 | 140 |
| Jelly (grape) | 10 | .... | 26 |
| Total (computed) | .... | 3.46 | 617 |
| Supper: | | | |
| Potato (fried) | 57 | .23 | 102 |
| Meat (roast beef) | 30 | 1.07 | 116 |
| Bread ("war bran bread") | 45 | .85 | 157 |
| Cocoa | 125 | .46 | 89 |
| Peach (canned) | 41 | .05 | 20 |
| Chocolate cookies | 16 | .18 | 69 |
| Jelly (grape) | 10 | .... | 26 |
| Total (computed) | .... | 2.84 | 579 |
| Total for day (computed) | .... | 8.76 | 1,695 |
| In composite sample for day (determined) | .... | 8.25 | 1,306 |
| Extras not in sample (computed): | | | |
| Orange | 160 | .21 | 86 |
| Jelly | 30 | .... | 77 |
| Sugar | 9 | .... | 36 |
| Bran | 12 | .32 | 50 |
| Total for day | .... | 8.78 | 1,555 |

## PROPORTIONS OF NUTRIENTS IN THE DIET.

As previously stated, no attempt was made to secure either high or low protein in the diet, the adjustment being made wholly upon the caloric content. The lowering of the energy automatically resulted in a lowering of the protein. The actual protein intake can be obtained for practically any day for any one of the subjects by multiplying the nitrogen in the food (see tables 46 to 70) by the standard factor 6.25. It was impossible to complicate the entire research by an attempt to apportion the non-protein energy between fat and carbohydrate.

A careful inspection showed there was no deficiency of either; in other words, there was no excessive fat or excessive carbohydrate. To obtain an approximate estimate of the relative proportion of fat and carbohydrate in the food, certain composite samples were analyzed, the fat being determined by ether extraction and the total carbohydrates by hydrolysis. The results of these analyses are given in table 30. These were not used for computing the total energy of the day, for to these materials should be added the nitrogen and energy of certain staples, such as sugar, bran, jelly, butter, etc. They serve to show, however, that the diets were by no means deficient in fat. The results given for November 20, 1917, are for a normal group with uncontrolled diet. Roughly speaking, the fat in the diet on November 20 is twice that in the other two samples analyzed and the carbohydrates are increased by approximately the same percentage.

TABLE 30.—*Fats and carbohydrates determined in typical composite samples of food.*

| Squad and date. | Sample. | Weight of partially dried sample. | Total fats. | Total carbohydrates. |
|---|---|---|---|---|
| | | *gms.* | *gms.* | *gms.* |
| Squad A, reduced diet, Oct. 9, 1917.. | *a* | 362 | 44.1 | 178.7 |
| | *b* | 357 | 47.8 | 171.5 |
| Average.................... | ........ | .......... | 46.0 | 175.1 |
| Squad A, reduced diet, Dec. 5, 1917.. | *a* | 351 | 33.7 | 167.4 |
| | *b* | 340 | 34.8 | 158.2 |
| Average.................... | ........ | .......... | 34.3 | 162.8 |
| Normal diet, group of 12 men, Nov. 20, 1917........................ | *a* | 661 | 83.1 | 340.8 |
| | *b* | 660 | 95.6 | 342.2 |
| Average.................... | ........ | .......... | 89.4 | 341.5 |

## EXTRA FOODS.

In the case of the 12 normal men studied in the experiment of November 20 to 24, inclusive, extra foods were eaten away from the table (see table 32), but with Squads A and B no foods were consumed away from the table on the days with controlled diet. On the other hand, a regrettable feature in the study with Squad A was the desire of most of the men to chew gum excessively. For a few days gum-chewing was allowed *ad libitum*, but no record was made of the amounts used. Later it was recognized that an appreciable amount of energy was supplied by soluble carbohydrates in the gum. Thereafter records of the gum used were made for all of the men in both squads during the diet restriction.

cent of the total nitrogen and, of still more significance, 10 per cent of the total calories ingested. (See table 32.)

TABLE 32.—*Computed nitrogen and energy in food of normal group of 12 men, Nov. 20 to 24, 1917.*

[Values per man per day.]

| Date. | In total food including "extras." | | In "extras." | |
|---|---|---|---|---|
| | Nitrogen. | Energy (gross). | Nitrogen. | Energy (gross.) |
| | *gms.* | *cals.* | *gms.* | *cals.* |
| Nov. 20..... | 20.80 | 4,246 | 1.52 | 536 |
| 21..... | 17.06 | 4,174 | .64 | 417 |
| 22..... | 17.95 | 3,961 | .90 | 316 |
| 23..... | 17.08 | 4,023 | .60 | 362 |
| 24..... | 19.41 | 4,117 | 1.02 | 414 |
| Average.. | 18.46 | 4,104 | 0.94 | 409 |

## UNCONTROLLED MEALS.

Ideally, an experiment such as this should be carried out with every meal controlled. Practically, although we enjoyed the fullest cooperation of the subjects, it became psychologically impossible to control every meal throughout the entire period of 4 months. Consequently, the men were allowed an uncontrolled diet on the Sundays following the biweekly experiment in Boston. They were specifically cautioned, however, to control the diet so far as possible and to make reports of what they ate. At the Thanksgiving recess for a few days it again became necessary to allow the men uncontrolled diet. Again, during the Christmas vacation, a number of the men went to their homes. For several of them this was possibly a farewell visit, as they were going into active war service; under the circumstances we could not urge them to remain in Springfield for the holidays. They were, however, requested to curtail the diet in so far as they could and to endeavor to return to Springfield as nearly as possible with no change in body-weight. More than this we could not conscientiously do. Subsequent inspection of the data returned by these men as the record for the uncontrolled meals on Sundays made us regret extremely that we did not urge more strongly the desirability of complete control throughout every meal, even at the sacrifice of shortening the entire experiment. Some of the Sunday meals were excessive in amount in both nitrogen and calorie content. It would seem almost incredible that such quantities of food could be eaten without extreme discomfort. In fact, a certain amount of discomfort was produced in a majority of cases.

An extreme case of an uncontrolled Sunday diet is that given in table 33 for *Gul* on January 13. On this day the food ingestion began with the standard laboratory breakfast, followed by several light lunches

TABLE 33.—*Sunday diet (uncontrolled), typical of large intake of nitrogen and energy—Gul, Squad A, Jan. 13, 1918.*

| Kind of food. | Nitrogen.[1] | Energy.[1] | Kind of food. | Nitrogen.[1] | Energy.[1] |
|---|---|---|---|---|---|
| *Breakfast.* | *gms.* | *cals.* | *Dinner.* | *gms.* | *cals.* |
| At laboratory: | | | Soup, tomato | 0.65 | 97 |
| Roll | 0.53 | 104 | Beefsteak (4 pieces) | 14.92 | 676 |
| Banana (one-half) | .11 | 50 | Potato (2 helpings) | .84 | 230 |
| Milk, topped (1 pint) | 2.07 | 203 | Gravy (2 helpings) | .35 | 65 |
| Shredded wheat | .48 | 113 | Coffee | .16 | 62 |
| Jelly | ....... | 67 | Ice cream (2 dishes) | 1.08 | 523 |
| Sugar | ....... | 40 | | | |
| At restaurant: | | | *Supper.* | | |
| Griddle cakes (2 orders) | 2.80 | 861 | Toast (3 pieces) | .92 | 188 |
| Coffee | .16 | 62 | Coffee (2 cups) | .32 | 124 |
| | | | Custard pie | 1.17 | 330 |
| Extras— | | | Cookies (four) | .67 | 260 |
| Apple | .09 | 85 | Peas | .49 | 52 |
| Chocolates (½ lb.) | ....... | 892 | Butter (1 pat) | .02 | 80 |
| Bran | .64 | 100 | | | |
| Epsom salts | ....... | ....... | Total for day | 28.47 | 5,264 |

[1] Computed.

after the subject left the Laboratory, with a very large dinner and a large supper, although the exact distinction between dinner and supper is somewhat in doubt. Suffice it to say that *Gul* on this day obtained over 28 grams of nitrogen and 5,264 gross calories of energy.

Although we had to base our computations not only for this subject but for all others upon their personal statements, with no weighings and only approximate estimates as to the composition of the cooked foods, we have computed the probable nitrogen and energy intake of the subjects on the uncontrolled Sundays, including, also, the laboratory breakfast. This is of such general interest, especially in subsequent discussion, that it is deemed important to present it in considerable detail in table 34. In general the amount of food eaten was very large, the caloric intake being on the average not much different from that obtained for the normal group of 12 men from the Y. M. C. A. College studied from November 20 to 24. (See table 32.) The average nitrogen intake on these uncontrolled Sundays was 16.62 grams nitrogen, and the average gross energy was 3,994 calories. Comparing these amounts with the actual food consumption at or about this period, it can be seen that the excess in the nitrogen and energy intake was large during the break in training on these days.

This excess food has been for us a perplexing problem, the sudden ingestion of a large amount of nitrogen interfering considerably in the intelligent interpretation of our results. The sudden ingestion of a large amount of energy has not been so confusing, for the men invariably took considerable exercise on subsequent days or voluntarily curtailed their diet to offset the excess intake. So far as possible,

therefore, we have indicated the probable nitrogen and energy intake of the men in Squad A on the uncontrolled days. Squad B, when on diet, had no uncontrolled meals; hence this problem of uncertainty does not enter into the consideration of their results.

TABLE 34.—*Computed nitrogen and energy in Sunday diets*[1] *(uncontrolled), Squad A.*

| Subject. | Nitrogen. | | | | | Energy (gross). | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Oct. 28. | Nov. 11. | Nov. 25. | Dec. 9. | Jan. 13. | Oct. 28. | Nov. 11. | Nov. 25. | Dec. 9. | Jan. 13. |
| | *gms.* | *gms.* | *gms.* | *gms.* | *gms.* | *cals.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Bro.... | 15.13 | 14.05 | 16.13 | 15.46 | 20.09 | 3,758 | 3,951 | 3,797 | 4,152 | 4,385 |
| Can.... | 13.45 | 13.30 | 13.14 | ....... | 17.54 | 3,088 | 3,229 | 3,347 | ....... | 3,964 |
| Kon.... | 12.34 | 18.36 | 24.01 | ....... | 28.47 | 2,377 | 4,569 | 5,256 | ....... | 5,264 |
| Gar.... | 14.67 | 23.63 | ....... | 24.53 | 15.34 | 3,403 | 4,978 | ....... | 4,561 | 4,521 |
| Gul.... | 14.01 | ....... | 14.05 | 14.95 | 28.47 | 3,671 | ....... | 4,830 | 5,355 | 5,264 |
| Mon... | 12.29 | 8.77 | 13.38 | 12.39 | 15.80 | 2,153 | 3,054 | 4,660 | 3,324 | 3,955 |
| Moy... | 17.11 | 14.34 | 17.00 | 18.82 | 32.70 | 3,971 | 3,948 | 4,763 | 4,795 | 6,038 |
| Pea.... | 23.24 | 16.15 | 13.42 | 21.25 | 21.20 | 7,537 | 4,522 | 3,310 | 5,666 | 5,221 |
| Pec.... | 18.83 | 11.69 | 17.44 | 20.15 | 11.30 | 3,016 | 2,650 | 3,541 | 4,414 | 2,900 |
| Spe.... | 14.73 | 8.93 | 12.82 | ....... | ....... | 3,248 | 3,241 | 3,369 | ....... | ....... |
| Tom... | 13.52 | 15.19 | 15.64 | 13.62 | 16.12 | 2,525 | 2,925 | 3,597 | 3,347 | 3,024 |
| Vea.... | 16.01 | 15.58 | 12.38 | 19.79 | 11.27 | 4,057 | 3,647 | 3,063 | 4,586 | 2,524 |
| Av.[2].... | 15.44 | 14.54 | 15.40 | 17.88 | 19.85 | 3,567 | 3,701 | 3,958 | 4,467 | 4,278 |

[1] The uncontrolled diets of Sunday, October 14, 1917, were not reported.
[2] The average nitrogen intake for these Sundays was 16.62 grams and the average gross energy 3,994 calories.

In the last analysis, however, it should be borne in mind that these men were, in a sense, on controlled diet even during these unrestricted periods, for the actual control was the body-weight. They were thoroughly educated in the belief that an increase in body-weight indicated overeating. Judging from the character of the food in the restricted diet, the men had evidently for the most part a relatively low glycogen storage. We have every reason to believe that many of the increases in weight noted with these men were due to the fact that there was on the free days a liberal storage of glycogen, which carried with it a large amount of water. This addition of water would accentuate the increases in weight, a point which has been thoroughly discussed in the section on body-weight. (See pp. 194 and 224.) On the other hand, the men soon found that by rigid training the weight gain could be rapidly lost and the original desired level speedily obtained.

## CALORIC ALLOTMENT.

The caloric allotment with Squad A was determined primarily with a view to lowering the body-weight to approximately 10 per cent below the initial weight and subsequently providing sufficient calories to maintain the body-weight at that level. It was believed that

tein, fats, or carbohydrates, was insisted upon. The sole aim was to alter the energy sufficiently to produce loss in body-weight to a definite point and thereafter to increase the energy only when needed to hold the body at that weight-level.

### INTROSPECTION REGARDING DIET.

The data regarding the diets recorded in the previous portion of this chapter are based upon the quantitative measurements. It seems important also to record such of the introspection as is relevant to the character, amounts, palatability, etc., of the diet. As records of the state of mind of these men at the different stages in the experiment, these introspections form a real contribution to the study. The phraseology used by the men is given in most instances, and frequently these statements are given *verbatim*.

#### SQUAD A.

On the evening of November 10, while at the Nutrition Laboratory, the men were questioned individually along certain lines on the ground that by this time they were accustomed to the experiment and the element of suggestion would play a very small rôle. The questions pertaining to food, together with the answers given by the several subjects, are reported herewith. Records were likewise kept concerning the introspection previous to November 10, which was doubtless colored by the novelty of the situation. In addition, we have the introspections recorded on the various trips to Boston, chiefly in connection with the psychological tests, the chance remarks regarding the diet made at Springfield and noted by the experimenters throughout the entire test, and the introspections (retrospect) obtained by one of us after the close of the experiment on special trips to Springfield.

To avoid repetition we give herewith the substance of the three questions asked of each member of Squad A on November 10; the answers thereto will be found under this date for each subject. (1) What part of the whole experiment thus far has caused you personally the most discomfort or pain, if any? Have hunger pains been experienced, and if so, when? (2) What part of the present diet seems a necessity to you; that is, what tastes best to you or what do you relish most? (3) If allowed to order a meal without restriction, what would you ask for, *i. e.*, what foods have you missed most thus far in the experiment?

GREYSON C. GARDNER (GAR).

*November 10, 1917.*—Hungry for 20 minutes or half hour immediately after meals and again about an hour before meals. Likes dessert better than anything else; craves pie and cake especially, also pudding.

*November 24, 1917.*—No trouble with the diet.

*February 2, 1918.*—Was hungry all the time before Christmas. The chief difficulty thus far has been his inability to eat in company with people who were having a social time eating together. Has not noticed being hungry

meal whenever it comes. Likes bulky things, as rye bread and carrots. Has no craving for anything special, except for a good meal.

*November 16, 1917.*—Expresses more or less dislike to having his food reduced.

*November 18, 1917.*—Remarked yesterday that he preferred to omit from diet all or part of meat and get more bulk.

*December 12, 1917.*—Has had no bowel movement since first part of week (two or three days). Never calls for bran, but did so to-day.

*January 12, 1918.*—Spent Christmas vacation in hospital; operation for hemorrhoids. "I refused meat in the hospital."

*February 2, 1918.*—Says chief inconvenience of experiment has been in having to save urine and feces, but hunger has not troubled him so much. Manages a store and is busy every minute of day and no time to think about being hungry; believes it is because of continuous occupation that he has not noticed hunger so much as some of subjects.

*February 6, 1918.*—Sick; thinks it due to beans eaten at Laboratory. Has been sick all the week with his stomach. Went to *Pec's* last night and ate more than *Vea.* Went home sick to-day.

*February 8, 1918.*—*Bro* reports: "I think Mr. Tompkins has returned to his previous condition of piles; that he ate so much following the experiment that he was put out of condition."

*February 28, 1918.*—"Immediately after the experiment I could not seem to eat enough, which caused considerable discomfort, but that has now disappeared and I am eating normally again."

KIRK G. MONTAGUE (MON).

*October 27, 1917.*—"I am hungry and sleepy; otherwise all right."

*November 10, 1917.*—"I know that normally I had been eating too much and I can not help but notice the big change." Has felt no pain at any time; feels weak naturally, because hungry; has not felt hungry until this last reduction in diet; hunger comes on before and after supper. Hard to say what article of diet he enjoys most, because he always enjoys eating everything. Misses ice cream more than anything else. Is hungry all the time or else it is imagination.

*November 12, 1917.*—Has gas in stomach (after free Sunday).

*November 24, 1917.*—"I feel better since they have been giving us some bran."

*December 8, 1917.*—"Yesterday and to-day I have felt better since I have been given more food, as I was 2 full kilograms underweight."

*December 19, 1917.*—"Not so hungry as I was. More to eat now." (Records show he was getting 2,672 net calories in the latter part of December as compared with 1,935 calories in the early part.)

*January 7, 1918.*—Abstained from food completely for two days (Saturday and Sunday, January 5 and 6, 1918) to reduce weight.

*February 2, 1918.*—Says decidedly that present diet is not sufficient to satisfy hunger. Found a great deal of comfort in chewing gum, as several of the subjects have.

*February 6, 1918.*—Extra large serving of food at dinner. Ate lightly at night. "Professor Burr conducts very interesting classes, but even he notices that we go to sleep in class now. We fall asleep from eating too much."

*February 8, 1918.*—"There is no weakness or hunger now. Food is not repulsive, and has not been at any time since uncontrolled eating began, nor have I been nauseated. I can study better and I can do my physical work better. On Monday, Tuesday, and Wednesday I had diarrhea; no pain

not to overeat. Tuesday evening I had a 'big feed' at Mr. Peckham's and after it I felt very uncomfortable, but I had no stomach-ache or indigestion." States that during the diet period when he was hungry he found it most satisfactory to run the typewriter or do some such work rather than try to study; could do as much on Sunday after his full dinner as during the rest of the week, or at least this was his impression.

*May 21, 1918.*—Is at present eating only two meals a day—breakfast and dinner; did this particularly when writing his thesis, in order to save time and also some money, and because he was convinced he did not need supper. Probably has been eating a little heavier dinner, but not any heavier breakfast. For breakfast has two glasses whole milk, two shredded-wheat biscuits, two slices of bread with butter, and fruit, if there is any. Is sure he is eating very much less food than he did just after the close of the experiment, and thinks he is eating somewhat less than he did normally before the experiment. Between meals during the day sometimes eats three or four chocolates, sometimes not any. Is rather surprised that, since leaving off supper, he does not seem to have a particularly keen appetite for breakfast or dinner.

R. Wallace Peckham (Pec).

*October 27, 1917.*—"I am very happy to be on the diet squad."

*November 10, 1917.*—"The amount of food seems mighty small." Has a gnawing pain of hunger about 3 hours before eating; noticeable first 10 days and increased in severity last 2 days, due to fact he had been trying to lose weight by increased physical exercise. Everything tastes good to him, shredded wheat more than anything else. Craves salad, pie, doughnuts, and Rhode Island johnnycakes, probably explained in part by the fact that his family has them at home on the table and he sees them.

*November 18, 1917.*—Prefers after to-day to leave out of the diet all or part of meat and get more bulky food instead.

*November 26, 1917.*—"Had a pretty good feed Sunday. Look at my face! See, all the wrinkles are gone!"

*December 6, 1917.*—Reported as having made the following remark two days before: "We fellows must have reached a pretty bad place when we are ready to cry from hunger."

*December 19, 1917.*—"I feel fine as silk. Nothing difficult for me now and with this food I have more life and snap."

*January 7, 1918.*—Reports he has abstained from food completely for two days (Saturday and Sunday, January 5 and 6) to reduce weight.

*January 12, 1918.*—"No hunger pains now."

*January 26, 1918.*—"I have dreams at night about food."

*February 2, 1918.*—With present diet feels no keen sense of hunger. Dreams of food, but thinks it due to approaching end of experiment and that then he will live at home again; is naturally looking forward to it.

*February 5, 1918.*—Squad A went to *Pec's* to a turkey dinner and everyone "stuffed to the limit." *Pec* had second helping of ice cream.

*February 8, 1918.*—"I think the men should have been brought back to normal and not allowed to come end over end. Nearly everyone has had difficulty such as diarrhea. In my case it has been very extreme. I ate toast and tea and bran bread, but it continued from Monday evening, February 4, until to-day, February 8. Monday forenoon I was down town. During the period of the experiment I have often noticed in the windows exhibits of food for sale. It always looked most attractive. I went into a shop and bought two doughnuts with apple jelly inside and ate them. It was indiscreet to eat them, but otherwise I was very careful and did not overeat. At noon I had

he was getting considerable food. Thinks he could have stayed on that diet indefinitely; was getting practically enough to satisfy him. During actual period of reduction in attempt to lose 10 per cent (15 pounds or so) was uncomfortable and hungry all the time. Frequently, at night, would go to bed because of hunger, and realized he would sleep and in the morning would wake up and go through respiration experiment; then would get something to eat. "When you are getting a very small diet, for the hour and a half after the meal you notice being hungry more than before the meal; you feel almost starved, and crave any food you see; after that this condition seems to pass away. It was a hard matter to have the men at the other tables in the dining-hall eating so much and getting such large helpings and yourself be cut down so low."

GEORGE A. BROWN (BRO).

*November 10, 1917.*—1,402 net calories on this date. "At times I feel a little weak, but as compared with last year, when eating all I wanted, I now feel much better and have 'pep' left after the day is over." One of the greatest deprivations has been the fact he could not eat candy, etc., between meals; had been in the habit of getting candy and peanuts between meals when going downtown and passing a drugstore; has not felt painfully hungry at any time, but sometimes hungry just before supper. In general potatoes and milk taste best to him. Craves nothing except candy; would order a large steak with plenty of gravy.

*December 6, 1917.*—Was "terribly" hungry the other day; could not study.

*December 8, 1917.*—"I feel all right. It is too near meal-time to feel otherwise. I am occasionally hungry."

*December 12, 1917.*—In evening stomach feels rumbling and queer.

*December 19, 1917.*—"Not so hungry."

*January 12, 1918.*—Net calorie intake, 1,536 calories; previous two days, 699 and 883 calories. "I do not have enough to eat. I feel better now than right after supper. I seem to notice the reduction in food more this time than I did the first time. Perhaps the cut is a greater one."

*January 14, 1918.*—Hungry.

*January 15, 1918.*—Hungry.

*January 16, 1918.*—Weak but better (double portion of food).

*January 17, 1918.*—Feel good but lack "pep," *i. e.*, life and snap (double portion of food).

*January 26, 1918.*—Net calorie intake, 1,927; averaged about 1,500 calories for the previous 6 days. "The past few days I have been rather weak and hungry at times."

*January 29, 1918.*—Feel good (double portion of food).

*February 2, 1918.*—"Is the food you are now getting sufficient to satisfy hunger?" "Yes." "Any hunger pains?" "Not in the last two days." "What has been the chief disagreeable feature of the whole experiment to you?" "Feeling hungry and thinking of all the good things I might have to eat, but particularly hated to go without candy and sweet things of that nature."

*February 8, 1918.*—"Following the experiment I found that I had lots of gas and a sour stomach, no indigestion or diarrhea, or special pains. Concerning the experiment in general I think several of the men tried to arrange their work to accommodate themselves to the hunger. In my own case I could study pretty well following meals, but an hour or an hour and a half before meals I found it much better to occupy myself in arranging the books on the shelves in the library. I thought of the food so much and it had to be so scientific. If I only could have had a little candy I would have given

up all the bread in a meal for it. If I could have had the food and eaten it when and how I pleased, just the same amount, it would have seemed much better to me. That is, I wanted some freedom in reference to it. Think the matter of intense occupation a big factor in making one able to accommodate himself to a reduced diet and the presence of hunger. I would be willing to stake all on the absolute reliability of the men under the honor system. I would not have gone into the experiment if watched all the time, as then there would have been the attitude of trying to 'put something over'. Dr. Carpenter was at the Laboratory on the evening before the experiment ended when I had some candy or food and told me to be careful or the temptation might be too strong to take some. I laughed and stated that I had two dozen almond bars, several glasses of jelly, and other food in my room all the time, which had been sent me from home by my people or given by local friends. There was absolutely no temptation to take it under the circumstances, but had the people watched us and checked us, I do not know how it would have been then."

"You will have to hand it to Mr. Fox for being able to get on with the 12 men of our squad, who were so crabbed and complaining most of the time. When we found that the food was cut down, for example, the men complained in an almost rude fashion. Some fellow would say, 'Here, what does this mean; don't I get some of this to-day, or some of that other to-day?' Mr. Fox would just calmly reply: 'I did not plan on that.'"

*May 21, 1918.*—Is now going without midday meals; eats breakfast and supper and thinks that these are not heavier meals than he ate on the three-meal basis, and therefore that he is taking less food than he used to take normally. The experiment ended February 3. Up to the spring vacation, April 3, he ate three meals a day and the amounts eaten were considerably more between February 3 and April 3 than since that time. With regard to a statement sent to Professors Chittenden and Lusk that this régime was not recommended for the army or for men performing severe muscular labor, *Bro* said: "I should say not. I have myself at other times said, 'I should hate to see our soldiers put on that diet'. Under the conditions of an athletic contest two teams may go through substantially the same motions and the same team plays, but one team does it with more snap and gets there quicker; that team is going to win the game. It was just that added snap and punch that the men on the diet lacked and that would be the essential thing that a soldier must have in order to succeed."

In addition to the personal introspections of the men in Squad A regarding the diet, a few statements are given which were recorded by the experimenters during the progress of the experiment.

*October 30, 1917.*—"It seems as if most of the squad overate on Sunday, October 28; on talking with them they all claim that it knocked them out and they would not fill up again in the same way."

*January 21, 1918.*—"Complaint of hunger is *comparatively* infrequent."

*January 25, 1918.*—Written on calendar near table of diet squad: "10 more days, *then we will eat.*" The number of days was changed daily by one of the squad.

*January 29, 1918.*—"Everything is going on well. The only complaint is generally about being 'hungry'".

*January 30, 1918.*—"The end of it all is the talk of the town."

*January 31, 1918.*—"The craving for meat as the particular article of food which would be the most welcomed when the diet was discontinued

after the close of the experiment has never been mentioned, to my knowledge. A good dish of oatmeal with cream, griddle cakes with sirup, ice cream, pies, candy and plenty of it, cake, are the dishes which have generally been mentioned.''

*February 5, 1918.*—"The diet squad all went to *Pec's* to a turkey dinner and everyone 'stuffed to the limit.' Chef Hall gives our table special dishes of bulky food such as greens and vegetables."

*February 6, 1918.*—"Bread heavily covered with butter plentifully eaten. Everyone ate to the limit last night.'' "Men ate quite heavily the first part of the week, but are not eating so much now.''

### SQUAD B.

The data for the members of Squad B concerning introspection on diet are naturally not so extended as with Squad A. They are accorded here the same treatment as the statements of Squad A. The only note of general interest is the fact that bran was called for by several members of Squad B following the close of the experiment.

#### Edward M. Fisher (Fis).

*January 13, 1918.*—"I feel empty since being on the diet.''

*February 8, 1918.*—"I did not overeat after the experiment, although it was a great temptation to keep filling up all the time. During the last seven days I have taken just two meals a day. I found it necessary to cut down. I think I have gained about 3 kg. in weight. I took two doses of salts one week ago to help reduce.''

#### Victor H. Hartshorn (Har).

*January 13, 1918.*—Complains of weariness since going on diet.

*January 27, 1918.*—"Immediately after meals I am all right.''

*February 8, 1918.*—"Before I went on the diet experiment I was working at a boarding house and had much meat. A diet somewhat more than I was eating while on the experiment would be fine for me.''

#### Karl Z. Howland (How).

*January 13, 1918.*—"To-night I feel all right.''

*January 19, 1918.*—"I feel all right.''

*January 27, 1918.*—"I feel good to-night. This week all right, only I think of eating so much of the time.''

*February 8, 1918.*—"Do not feel so well, but my mind is more peaceful, as I can eat whatever I want and when I want it. If during the experiment it had been impossible to get extra food or to get candy I would have been more comfortable. I could have got on better, I believe, if there had been a real need for reducing because of universal scarcity of food.''

#### Robert L. Hammond (Ham).

*January 9, 1918.*—Can not eat fruit or jelly of any kind, as it does not agree with him. Was not obliged to eat it but was not given a substitute.

*January 13, 1918.*—Feels all right, except for lack of food.

*January 19, 1918.*—"I feel hungry, but otherwise all right.''

*January 27, 1918.*—"I feel fine. Could eat, but otherwise all right.''

#### Harold L. Kimball (Kim).

*January 13, 1918.*—"The rheumatism which has troubled me a great deal does not bother me now. It seems to be helped very much by the reduced diet.''

*February 8, 1918.*—"Since eating uncontrolled my teeth have begun to ache and the old rheumatism is back with a 'bang.' While on diet I could chew without difficulty. I am very much in favor of the diet for my health. After three days of eating the old troubles began to come back. It was not a case of overeating; I was careful, but I wanted meat and ate it."

ROBERT H. LONG (LON).

*January 13, 1918.*—"I mind the diet; that is, I noticed the lack of food considerably the first two days. Since then I have felt better. To-night I am all right."

*January 19, 1918.*—"I have not felt very well during the week. I feel fairly good to-night."

*January 27, 1918.*—"I feel better to-night than on any day this week."

JOHN SCHRACK (SCH).

*January 13, 1918.*—"I feel quite good, but hungry all the time; always thinking about good things to eat. I eat things now that I did not care for previously and they taste very good, too."

*January 19, 1918.*—"I feel fine; I have felt pretty good all the week."

*January 27, 1918.*—"I had gas in the stomach. Not very anxious to go off the diet. I have some things to eat with me, ready for tomorrow, but as hungry as I have been they do not appeal to me greatly."

ALFRED LIVINGSTONE (LIV).

*January 13, 1918.*—"I am always waiting for meal time to come. Otherwise I never felt better."

*January 22, 1918.*—"Very hungry."

*January 27, 1918.*—"Hungry."

CHESTER D. SNELL (SNE).

*January 13, 1918.*—"Never felt better in my life since I went on the diet."

*January 22, 1918.*—"Never felt better or more hungry."

*January 27, 1918.*—"I feel fine to-night. Never felt better in my life. I am even used to being hungry. It doesn't trouble me any more."

GEORGE H. THOMPSON (THO).

*January 19, 1918.*—"I have been hungry at times."

*January 22, 1918.*—"Feeling tired and hungry."

*January 27, 1918.*—"I feel fine. I have been living pretty good. This last week no fault to find with the experiment at all."

FLOYD M. VAN WAGNER (VAN).

*January 13, 1918.*—"I feel very good since on the diet. No difficulties at all."

*January 19, 1918.*—"I am well to-night and hungry. This week only the effects of hunger have been felt."

ELTON L. WILLIAMS (WIL).

*January 13, 1918.*—"The diet gives no discomfort. I have felt some hunger, though."

*January 19, 1918.*—"I am quite tired to-night. Hard basket-ball yesterday. Went to bed at $12^h30^m$ a. m.; up at 5 a. m.; was so hungry that I had to get up. I have had some pain in my stomach all the week."

*February 8, 1918.*—"Difficult to concentrate in study. I could not keep the idea of eating out of my mind. One of the easiest ways to forget eating was to typewrite notes. I missed candy greatly. If I were with people who were all getting low diet and had moderate physical work, as in camp life, it would be much easier."

correspond to the caloric intake. (See figs. 57 to 68, pp. 210 to 222.) In practically every instance the caloric intake was increased somewhat in the second week in December; in general the height of the block at this time and the height of the block for the last few weeks of the experiment are not far from the same. In other words, we have two periods which represent a fairly close approximation to the caloric intake for weight maintenance, *i. e.*, when the body-weight was either constant or not materially increasing or decreasing. At neither of these times had we the perfect control desired. Nevertheless, these two independent periods, some six weeks apart, give fairly good evidence of the probable maintenance requirement of these men at the lower weight-level.

If we examine the body-weight chart for *Bro*, (fig. 57, p. 210), we find that the initial requirement in the early part of this test on the uncontrolled days was somewhat over 3,000 calories. The calories here, as well as on the other charts, refer only to the net calories, *i. e.*, calories of food less those of feces and urine. On October 4 a diet restriction took place with a fall in energy intake to about 2,200 calories. Further reductions were made but in the early part of December the energy was increased. This increase was determined, not by calculating the number of calories beforehand, but simply by a gradual increase of the diet during this period until the body-weight had become constant. Exactly the same procedure was carried out in the latter part of January, but the assistant in charge of the apportionment at no time determined the exact caloric intake of the food. Thus, both of these levels were adjusted without a previous knowledge of the caloric requirement. This holds true for all of the subjects. On the return of the men to college in January, all of the subjects received a low diet for a short time, to compensate for the increase in body-weight during their absence. With *Bro* we find that the average of the period of maintenance diet in December and January is not far from 2,000 calories. Reference to the individual balance-tables (tables 46 to 58) confirms this. To make the details still clearer, an abstract is given in table 35 of the principal data in the several balance-tables, grouped with regard to the several periods of diet ingestion. Reference to the actual energy available to the body with *Bro* during the period from December 3 to 20 shows that he had 2,091 calories, and from January 16 to February 3, 1,931 calories, making an average for the two periods of 2,011 calories per day. Hence, we may argue that *Bro* at the lower weight-level required 2,000 net calories.

The body-weight chart of *Can* (see fig. 58, p. 212) likewise shows that during December there was an approximate period of maintenance and another similar period in January. From table 35 and from the height of the two energy blocks on *Can's* chart which, as stated before,

TABLE 35.—*Nitrogen in food, energy available to body, and nitrogen excreted in urine during periods with the different diet levels, Squad A.*[1]

[Averages per day.]

| Subject and dates. | Nitrogen in— | | Energy available to body. |
|---|---|---|---|
| | Food. | Urine. | |
| BRO. | *gms.* | *gms.* | *cals.* |
| Normal diet: | | | |
| Oct. 1–4, 1917 | 15.03 | 11.84 | 3,049 |
| Reduced diet: | | | |
| Oct. 4–15, 1917 | 11.67 | 11.12 | 2,189 |
| Oct. 15–30, 1917 | 10.86 | 10.40 | 1,877 |
| Oct. 30–Nov. 12, 1917 | 9.03 | 10.80 | 1,524 |
| Nov. 12–29, 1917 | 9.29 | 9.60 | 1,582 |
| Dec. 3–20, 1917 | 10.81 | 10.59 | 2,091 |
| Jan. 8–16, 1918 | 8.05 | 8.96 | 1,344 |
| Jan. 16–Feb. 3, 1918 | 11.49 | 11.01 | 1,931 |
| CAN. | | | |
| Normal diet: | | | |
| Oct. 1–4, 1917 | 15.35 | 13.76 | 3,123 |
| Reduced diet: | | | |
| Oct. 4–15, 1917 | 11.55 | 13.39 | 2,155 |
| Oct. 15–29, 1917 | 10.62 | 11.20 | 1,833 |
| Oct. 29–Nov. 5, 1917 | 9.67 | 10.95 | 1,516 |
| Nov. 5–16, 1917 | 10.03 | 10.97 | 1,664 |
| Nov. 16–29, 1917 | 11.61 | 11.38 | 2,178 |
| Dec. 3–20, 1917 | 12.65 | 11.41 | 2,479 |
| Jan. 7– 9, 1918 | 8.56 | 11.71 | 1,128 |
| Jan. 9–Feb. 3, 1918 | 14.15 | 12.87 | 2,386 |
| FRE. | | | |
| Normal diet: | | | |
| Oct. 1–4, 1917 | 15.33 | 12.90 | 3,069 |
| Reduced diet: | | | |
| Oct. 4–15, 1917 | 11.01 | 11.45 | 2,179 |
| Oct. 15–25, 1917 | 10.53 | 10.80 | 1,828 |
| KON. | | | |
| Reduced diet: | | | |
| Oct. 30–Nov. 29, 1917 | 9.46 | 11.70 | 1,569 |
| Dec. 3–20, 1917 | 10.08 | 13.10 | 1,869 |
| Jan. 12–Feb. 3, 1918 | 9.26 | 10.05 | 1,581 |
| GAR. | | | |
| Normal diet: | | | |
| Oct. 1–4, 1917 | 15.88 | 14.03 | 3,142 |
| Reduced diet: | | | |
| Oct. 4–15, 1917 | 11.47 | 11.81 | 2,167 |
| Oct. 15–29, 1917 | 10.30 | 10.78 | 1,791 |
| Oct. 29–Nov. 12, 1917 | 10.36 | 10.10 | 1,781 |
| Nov. 12–29, 1917 | 9.57 | 9.98 | 1,712 |
| Dec. 3–20, 1917 | 12.79 | 10.33 | 2,400 |
| Jan. 7–18, 1918 | 7.39 | 10.42 | 1,276 |
| Jan. 18–Feb. 3, 1918 | 10.49 | 9.90 | 1,847 |
| GUL. | | | |
| Normal diet: | | | |
| Oct. 1–4, 1917 | 15.57 | 12.60 | 3,177 |
| Reduced diet: | | | |
| Oct. 4–15, 1917 | 11.65 | 11.58 | 2,229 |
| GUL.—continued. | *gms.* | *gms.* | *cals.* |
| Reduced diet: | | | |
| Oct. 15–29, 1917 | 11.21 | 11.10 | 1,951 |
| Oct. 29–Nov. 12, 1917 | 9.16 | 10.06 | 1,554 |
| Nov. 12–29, 1917 | 9.41 | 9.47 | 1,711 |
| Dec. 3–20, 1917 | 10.39 | 10.24 | 2,005 |
| Jan. 5–13, 1918 | 6.65 | 9.07 | 1,063 |
| Jan. 13–Feb. 3, 1918 | 9.11 | 8.29 | 1,607 |
| MON. | | | |
| Normal diet: | | | |
| Oct. 1–4, 1917 | 15.67 | 12.84 | 3,155 |
| Reduced diet: | | | |
| Oct. 4–15, 1917 | 11.57 | 11.91 | 2,087 |
| Oct. 15–Nov. 1, 1917 | 11.06 | 10.88 | 1,792 |
| Nov. 1–19, 1917 | 9.45 | 10.93 | 1,594 |
| Nov. 19–29, 1917 | 11.10 | 10.94 | 2,153 |
| Dec. 3–10, 1917 | 10.75 | 12.88 | 1,935 |
| Dec. 10–20, 1917 | 13.98 | 11.35 | 2,672 |
| Jan. 7–15, 1918 | 11.00 | 10.54 | 1,895 |
| Jan. 15–Feb. 3, 1918 | 12.80 | 11.29 | 2,126 |
| MOY. | | | |
| Normal diet: | | | |
| Oct. 1–4, 1917 | 15.15 | 12.32 | 3,074 |
| Reduced diet: | | | |
| Oct. 4–15, 1917 | 11.56 | 11.02 | 2,164 |
| Oct. 15–29, 1917 | 11.06 | 11.70 | 1,908 |
| Oct. 29–Nov. 12, 1917 | 9.48 | 11.31 | 1,564 |
| Nov. 12–29, 1917 | 9.43 | 10.43 | 1,627 |
| Dec. 3–20, 1917 | 11.01 | 10.76 | 2,095 |
| Jan. 8–13, 1918 | 7.85 | 12.62 | 1,149 |
| Jan. 13–25, 1918 | 10.81 | 11.24 | 1,723 |
| Jan. 25–Feb. 3, 1918 | 11.27 | 10.91 | 1,958 |
| PEA. | | | |
| Normal diet: | | | |
| Oct. 1–4, 1917 | 15.47 | 13.31 | 3,127 |
| Reduced diet: | | | |
| Oct. 4–15, 1917 | 11.89 | 14.15 | 2,292 |
| Oct. 15–29, 1917 | 11.58 | 13.68 | 2,160 |
| Oct. 29–Nov. 16, 1917 | 10.16 | 12.22 | 1,736 |
| Nov. 16–29, 1917 | 11.68 | 10.32 | 2,174 |
| Dec. 3–20, 1917 | 13.22 | 11.36 | 2,549 |
| Jan. 7–25, 1918 | 9.22 | 10.01 | 1,508 |
| Jan. 25–Feb. 3, 1918 | 13.38 | 12.05 | 2,318 |
| PEC. | | | |
| Normal diet: | | | |
| Oct. 1–4, 1917 | 15.66 | 13.02 | 3,117 |
| Reduced diet: | | | |
| Oct. 4–15, 1917 | 12.13 | 12.89 | 2,124 |
| Oct. 15–29, 1917 | 11.57 | 12.15 | 1,862 |
| Oct. 29–Nov. 29, 1917 | 9.43 | 11.68 | 1,507 |
| Dec. 3–9, 1917 | 9.79 | 10.95 | 1,617 |

[1] See detailed results in tables 46 to 58.

TABLE 35.—*Nitrogen in food, energy available to body, and nitrogen excreted in urine during periods with the different diet levels, Squad A.*[1]—continued.

[Averages per day.]

| Subject and dates. | Nitrogen in— Food. | Nitrogen in— Urine. | Energy available to body. | Subject and dates. | Nitrogen in— Food. | Nitrogen in— Urine. | Energy available to body. |
|---|---|---|---|---|---|---|---|
| PEC—continued. | *gms.* | *gms.* | *cals.* | TOM—continued. | *gms.* | *gms.* | *cals.* |
| Reduced diet: | | | | Reduced diet: | | | |
| Dec. 9–20, 1917 | 11.48 | 11.23 | 2,196 | Oct. 13–30, 1917 | 10.67 | 9.48 | 1,812 |
| Jan. 5–20, 1918 | 8.10 | 11.04 | 1,326 | Oct. 30–Nov. 19, 1917 | 8.89 | 9.31 | 1,400 |
| Jan. 20–Feb. 3, 1918 | 9.57 | 9.78 | 1,619 | Nov. 19–28, 1917 | 9.16 | 7.32 | 1,705 |
| | | | | Dec. 3–14, 1917 | 7.92 | 7.41 | 1,506 |
| SPE. | | | | Dec. 14–20, 1917 | 9.76 | 8.11 | 1,953 |
| Normal diet: | | | | Jan. 12–25, 1918 | 7.60 | 7.48 | 1,289 |
| Oct. 1–4, 1917 | 16.09 | 14.35 | 3,208 | Jan. 25–Feb. 3, 1918 | 8.82 | 7.71 | 1,662 |
| Reduced diet: | | | | | | | |
| Oct. 4–15, 1917 | 11.72 | 12.25 | 2,185 | VEA. | | | |
| Oct. 15–29, 1917 | 10.89 | 11.75 | 1,864 | Normal diet: | | | |
| Oct. 29–Nov. 12, 1917 | 9.69 | 11.78 | 1,656 | Oct. 1–4, 1917 | 15.57 | 13.88 | 2,821 |
| Nov. 12–17, 1917 | 10.00 | 11.57 | 1,524 | Reduced diet: | | | |
| Nov. 17–29, 1917 | 11.52 | 11.00 | 2,302 | Oct. 4–15, 1917 | 11.61 | 11.24 | 2,247 |
| Dec. 3–13, 1917 | 11.61 | 11.50 | 2,173 | Oct. 15–30, 1917 | 10.64 | 10.81 | 1,855 |
| | | | | Oct. 30–Nov. 12, 1917 | 9.05 | 10.40 | 1,486 |
| TOM. | | | | Nov. 12–29, 1917 | 8.58 | 10.05 | 1,498 |
| Normal diet: | | | | Dec. 3–20, 1917 | 9.57 | 10.22 | 1,836 |
| Oct. 1–4, 1917 | 14.91 | 9.66 | 3,082 | Jan. 7–15, 1918 | 9.81 | 9.14 | 1,609 |
| Reduced diet: | | | | Jan. 15–Feb. 3, 1918 | 11.36 | 10.95 | 1,909 |
| Oct. 4–13, 1917 | 11.43 | 9.75 | 2,081 | | | | |

[1] See detailed results in tables 46 to 58.

were independently established by simply giving such an amount of food as would hold the weight constant without the pre-determination of the caloric value, we find that during the first maintenance period (December 3 to 20) he required 2,479 calories and during the second period, (January 9 to February 3) the requirement was 2,386 calories. A close examination of the curves, however, shows a slight tendency for the body-weight to fall during these periods and we may state in round numbers that *Can* required 2,500 calories for maintenance at this lower level.

With *Kon* the conditions are somewhat different, inasmuch as he joined Squad A several weeks after the experiment was begun. The reduction in diet was therefore somewhat stringent and no clearly defined period of constancy in body-weight can be noted from the body-weight curve. (See fig. 59, p. 213.) There is, however, a tendency for the body-weight to be maintained at constancy between December 3 and 20, although the last weight shows a decided fall. In January the energy intake was adjusted to a lower level to compensate for the great increase in body-weight during the Christmas recess; during the last 10 days in January the weight remained very constant at this caloric intake. If we are to consider this energy

The unfortunate illness of *Spe* necessitated the conclusion in December of the observations with him. His chart, however, shows with reasonable clearness that the intake of about 2,200 calories would suffice to hold his body-weight constant. (See fig. 66, p. 220.) Unfortunately, in this instance we have not the usual verifying period during January.

The subject most sedentary in habits, and the one who had the most difficulty in securing a reduction in weight, was *Tom*. Unquestionably, the calories in the diet during the first few days were more than he needed, and the dietetic curtailment prescribed for the rest of the men was not sufficient to reduce his body-weight; the intake was accordingly lowered still further. The blocks in his body-weight curve, (see fig. 67, p. 221), show an approximate constancy at the lower weight level with an intake of not far from 1,600 calories. This subject did not lose as much weight as the others, and his loss of nitrogen was materially less than that of the other men.

One of the most regular body-weight curves in the whole series is that of *Vea*, who lost weight very regularly, established an approximate level with 1,850 calories in December, and again essentially the same level in January with 1,900 calories. (See fig. 68, p. 222.) We may thus take 1,900 calories as his probable maintenance requirement.

We have presented in table 36 the probable caloric requirements of these men for maintenance at the lower weight-levels. These values, given in round numbers, range from a minimum of 1,600 calories with *Kon*, *Tom* and *Pec* to a maximum of 2,500 calories with *Can*. At first sight *Can's* requirement appears inconsistent, for although *Can* was the heaviest man in the group, he was by no means so active athletically as some of the other men. The man who was probably the most active (*Pea*) shows, however, a maintenance requirement of 2,400

TABLE 36.—*Net energy required for weight maintenance at low weight-level—Squad A.*

[Derived from body-weight curves. See figs. 57 to 68.]

| Subject. | Calories. | Subject. | Calories. | Subject. | Calories. |
|---|---|---|---|---|---|
| Bro..... | 2,000 | Mon.... | 2,000 | Tom.... | 1,600 |
| Can..... | 2,500 | Moy.... | 2,000 | Vea..... | 1,900 |
| Kon.... | 1,600 | Pea..... | 2,400 | | |
| Gar..... | 2,000 | Pec..... | 1,600 | Avg... | 1,967 |
| Gul..... | 1,800 | Spe..... | 2,200 | | |

calories. To those of us who know the men individually, the most surprising figures in the table are the low values with *Pec* and *Kon*. With *Kon*, it will be remembered, somewhat unsatisfactory figures were obtained, and we are uncertain as to whether the energy intake cited is the actual maintenance level. On the other hand, the

picture for *Pec* is reasonably clear. It is not impossible that the latter's age (44 years) may have had an effect upon the energy requirement, for we know that the older a man is the greater the tendency is towards a lower basal metabolism. Averaging the values for the 12 men, we have an average value of 1,967 net calories for maintenance at the lower weight-level, *i. e.*, in round numbers, 1,950 net calories.

The significance of this low figure is perhaps best emphasized when one refers to the probable caloric requirement for weight maintenance prior to dietetic restriction. For this we have two sources of information: (1) the nitrogen balance (see tables 46 to 58, pp. 312 to 341) and (2) the summary in table 35 of the net caloric intake in the so-called "normal diet" from October 1 to 4; this intake averaged not far from 3,100 calories. If we examine the nitrogen in the food for these days, also given in table 35, it is clear that the amounts of food taken by these men were not the amounts normally taken by them. In the first place, they could not consciously have selected so uniform a nitrogen intake as they actually showed. In the second place, Chef Hall, who was very observant, pointed out to us that the men in Squad A in the normal-diet period of October 1 to 4 showed less appetite for their food than previously. On the first return of the college students in the autumn, they usually eat with great appetite, as the food is new to them and they enjoy it very much. There is then a period, usually of a week or ten days, when there seems to be a distinct slackening in the appetite, this actually having an effect upon the purchase and preparation of food in the kitchen. Subsequently they return to their normal appetite and food intake. It was our misfortune to have selected this period of low appetite in which to study the normal diet of these men. Mr. Hall's observation seems to be fully verified by the results of a study with a control squad on normal diet November 20 to 24, which are given in table 32 (p. 268). On 5 days 12 men showed an average energy intake of 4,104 gross calories per day. Deducting approximately 8 per cent, or 328 calories, for the energy outgo in urine and feces, we have 3,776 calories as the average net calories available for this period.

An inspection of the data for the calories in feces and urine for the first three days of October in the several balance tables (pp. 312 to 341) shows that the estimate of 8 per cent for outgo in urine and feces is not unreasonable. This would imply, therefore, that the normal food requirement of the average undergraduate student in the Springfield Y. M. C. A. College was, during the period of November 20 to 24, when this control squad was studied, nearer 3,800 calories than the 3,100 calories shown for Squad A in table 35. On the assumption that the normal energy requirement is 3,800 calories, the average caloric requirement of 1,950 calories found to hold the body-weight at the lower level was thus a little over one-half of the normal require-

ment; in other words, the caloric requirement had been lowered nearly one-half. Using the level of 3,100 calories actually found with Squad A from October 1 to 4, we see that the dietetic restrictions have lowered the caloric requirement 1,150 calories, or a little more than one-third. Even if we raise slightly the caloric requirement at the lower level of body-weight, we would still have reduced the normal requirement of 3,100 calories not less than one-third. It must again be pointed out, however, that body-weight is a very uncertain criterion of the condition of the body reserves. A period of two weeks is too short to obtain results of definite significance. In this particular case, however, with the majority of our subjects two periods separated by nearly a month or six weeks indicated approximately the same uniformity of weight-level with the same caloric intake; hence, we believe we are more justified in using these short periods of constancy in body-weight as a measure of maintenance than if we had but one period. The general conclusion can be drawn, therefore, that using the constancy in body-weight at the lower level as a criterion, the food requirements are approximately one-third less than they are at the higher level.

## DIGESTION EXPERIMENTS.

Normal, healthy man, subsisting upon modern well-prepared and well-cooked food materials, exhibits a uniformity of digestive processes that is, in a sense, rather remarkable. The so-called "digestibility" of our modern food materials can be predicted from standard figures with great accuracy. Hence a digestion experiment as such, particularly when ordinary food materials are used, is hardly justifiable. On the other hand, with a great restriction in diet, the evidence is not sufficiently extensive to show whether or not there would be a disturbance in the digestive processes. One criticism of the classic experiment of Professor Chittenden[1] with soldiers was that the amount of nitrogen excreted in the feces of a group of men, presumably with low diet, varied within very wide limits from that which would be expected, or was regularly found with normal individuals. This suggested the possibility, at least, that a restriction in protein had resulted in an actual disturbance of the digestion processes. It therefore became necessary with our subjects to make periodic, so-called "digestion experiments."

These digestion experiments were made with two purposes in view: (1) to note abnormalities if they existed, and (2) to give positive information as to the amount of unoxidized material leaving the body from the alimentary tract. Theoretically, it would have been best to have had a collection of feces throughout the entire time, but this presented technical difficulties which were so great as to make such

[1] Chittenden, Physiological economy in nutrition, New York, 1907, p. 131.

tained to show that fasting does not completely kill the bacterial action, for Professor Kendall[1] found bacteria in the colon. With the confusion existing at the present time, not only as to a classification of the exact facts known, but more especially with regard to the absence of any logical method of procedure, we must for the present adhere simply to the original plan of considering the nitrogen in the feces as being derived from food, and express our results according to the commonly accepted method.

In our digestion experiments we do not consider the digestibility of fat. It should be pointed out here that the common methods for analyzing the feces are wholly unsuited for the proper determination of the digestibility of fats, for the very large proportion of soaps in feces which are insoluble in ether makes a crude ether extract of feces wholly unsuitable for an estimate of the total fat content. In this research we are primarily interested in the question of whether or not there is a profound disturbance in the proportion of nutrients digested, as commonly expressed, when a diet is used which is very low in calories and moderately low in nitrogen.

### DIGESTION EXPERIMENTS WITH SQUAD A ON REDUCED DIET.

The results of our observations for Squad A are recorded in table 37 in grams of nitrogen per day in food and feces and in calories of energy per day in food, feces, and urine. The total and percentage of nitrogen utilized, and the total and percentage of energy available are also given. The differences in the utilization of nitrogen between the beginning and end of the experiment are extremely small, rarely amounting to more than 4 per cent. Hence it would be incorrect to state that there was a pronounced relationship between the amount of nitrogen in food and the nitrogen utilized.

Special attention should be called to the fecal nitrogen. While the character of the diet and the necessity for changing individual diets to maintain weight made it impossible to secure uniformity of nitrogen intake in all instances, we find that on October 8 to 12, the nitrogen in the intake was relatively constant for all men, that is, the values were all between 12 and 12.5 grams. The fecal nitrogen per day for these 12 men was as follows: 1.54, 1.35, 1.56, 1.33, 0.96, 1.22, 1.41, 1.22, 1.37, 1.33, 1.21, 1.02 grams, respectively; in other words, there was a maximum variation of 0.60 gram. This means, then, that when the same amount of food and essentially the same combinations of food, with practically the same nitrogen content, passed through 12 digestive tracts, the fecal nitrogen varied only from 0.96 to 1.56 grams. The period of study was, however, only 4 days. Since this particular test was begun on the fifth day of the restriction in diet, it is hardly probable that we can consider it as more than a normal

[1] Benedict, Carnegie Inst. Wash. Pub. No. 203, 1915, p. 232.

TABLE 37.—*Nitrogen utilized and energy available from food in digestion periods—Squad A.*

| Subject. | Date. | Nitrogen per day— | | Nitrogen utilized. | | Energy per day— | | | Net energy. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (*a*) In food. | (*b*) In feces. | (*c*) Total (*a-b*). | (*d*) Per cent $\frac{(c\times 100)}{a}$ | (*e*) In food. | (*f*) In feces. | (*g*) In urine ($N\times 8.0$) | (*h*) Total [$e-(f+g)$] | (*i*) Per cent $\frac{(h\times 100)}{e}$ |
| Bro.... | Normal diet: | *gms.* | *gms.* | *gms.* | | *cals.* | *cals.* | *cals.* | *cals.* | |
| | Oct. 1-4, 1917... | 15.03 | 1.95 | 13.08 | 87 | 3,310 | 166 | 95 | 3,049 | 92 |
| | Reduced diet: | | | | | | | | | |
| | Oct. 8-12, 1917.. | 12.41 | 1.54 | 10.87 | 88 | 2,322 | 171 | 91 | 2,060 | 89 |
| | Oct. 17-21, 1917.. | 11.09 | 0.72 | 10.37 | 94 | 1,979 | 124 | 90 | 1,765 | 89 |
| | Oct. 31-Nov. 4, 1917 | 8.12 | 0.73 | 7.39 | 91 | 1,487 | 105 | 85 | 1,297 | 87 |
| | Nov. 12-18, 1917.. | 9.58 | 1.24 | 8.34 | 87 | 1,672 | 160 | 81 | 1,431 | 86 |
| | Jan. 14-30, 1918.. | 9.74 | 1.18 | 8.56 | 88 | 1,831 | 145 | 80 | 1,606 | 88 |
| Can.... | Normal diet: | | | | | | | | | |
| | Oct. 1-4, 1917... | 15.35 | 1.36 | 13.99 | 91 | 3,367 | 134 | 110 | 3,123 | 93 |
| | Reduced diet: | | | | | | | | | |
| | Oct. 8-12, 1917.. | 12.31 | 1.35 | 10.96 | 89 | 2,320 | 147 | 111 | 2,062 | 89 |
| | Oct. 17-21, 1917.. | 10.98 | 0.86 | 10.12 | 92 | 1,970 | 113 | 100 | 1,757 | 89 |
| | Oct. 31-Nov. 4, 1917 | 9.07 | 1.07 | 8.00 | 88 | 1,724 | 138 | 93 | 1,493 | 87 |
| | Nov. 12-18, 1917.. | 10.32 | 1.24 | 9.08 | 88 | 1,911 | 168 | 93 | 1,650 | 86 |
| | Dec. 10-15, 1917.. | 13.59 | 1.76 | 11.83 | 87 | 2,972 | 231 | 88 | 2,653 | 89 |
| | Jan. 14-30, 1918.. | 14.37 | 1.76 | 12.61 | 88 | 2,734 | 215 | 104 | 2,415 | 88 |
| Fre..... | Normal diet: | | | | | | | | | |
| | Oct. 1-4, 1917... | 15.33 | 1.86 | 13.47 | 88 | 3,346 | 154 | 103 | 3,089 | 92 |
| | Reduced diet: | | | | | | | | | |
| | Oct. 8-12, 1917.. | 12.10 | 1.56 | 10.54 | 87 | 2,268 | 145 | 89 | 2,034 | 90 |
| | Oct. 17-21, 1917.. | 10.45 | 0.90 | 9.55 | 91 | 1,886 | 82 | 91 | 1,713 | 91 |
| Kon.... | Reduced diet: | | | | | | | | | |
| | Oct. 31-Nov. 4, 1917 | 9.04 | 0.87 | 8.17 | 90 | 1,574 | 125 | 103 | 1,346 | 86 |
| | Nov. 12-18, 1917.. | 8.65 | 1.06 | 7.59 | 88 | 1,487 | 150 | 95 | 1,242 | 84 |
| | Dec. 10-15, 1917.. | 9.06 | 1.07 | 7.99 | 88 | 1,952 | 150 | 96 | 1,706 | 87 |
| | Jan. 15-30, 1918.. | 7.79 | 0.88 | 6.91 | 89 | 1,502 | 129 | 78 | 1,295 | 86 |
| Gar.... | Normal diet: | | | | | | | | | |
| | Oct. 1-4, 1917... | 15.88 | 1.77 | 14.11 | 89 | 3,399 | 145 | 112 | 3,142 | 92 |
| | Reduced diet: | | | | | | | | | |
| | Oct. 8-12, 1917.. | 12.05 | 1.33 | 10.72 | 89 | 2,271 | 137 | 98 | 2,036 | 90 |
| | Oct. 17-21, 1917.. | 10.67 | 1.25 | 9.42 | 88 | 1,917 | 106 | 97 | 1,714 | 89 |
| | Oct. 31-Nov. 4, 1917 | 8.93 | 1.07 | 7.86 | 88 | 1,726 | 109 | 85 | 1,532 | 89 |
| | Nov. 12-18, 1917.. | 9.63 | 0.99 | 8.64 | 90 | 1,821 | 132 | 78 | 1,611 | 89 |
| | Dec. 10-15, 1917.. | 13.20 | 2.35 | 10.85 | 82 | 2,896 | 275 | 82 | 2,539 | 88 |
| | Jan. 14-30, 1918.. | 8.67 | 1.19 | 7.48 | 86 | 1,688 | 136 | 76 | 1,476 | 87 |
| Gul.... | Normal diet: | | | | | | | | | |
| | Oct. 1-4, 1917... | 15.57 | 1.13 | 14.44 | 93 | 3,385 | 107 | 101 | 3,177 | 94 |
| | Reduced diet: | | | | | | | | | |
| | Oct. 8-12, 1917.. | 12.37 | 0.96 | 11.41 | 92 | 2,331 | 140 | 117 | 2,074 | 89 |
| | Oct. 17-21, 1917.. | 11.61 | 1.01 | 10.60 | 91 | 2,087 | 149 | 99 | 1,839 | 88 |
| | Oct. 31-Nov. 4, 1917 | 9.50 | 0.87 | 8.63 | 91 | 1,780 | 129 | 89 | 1,562 | 88 |
| | Nov. 12-18, 1917.. | 9.53 | 0.91 | 8.62 | 91 | 1,688 | 127 | 83 | 1,478 | 88 |
| | Dec. 10-15, 1917.. | 10.44 | 1.54 | 8.90 | 85 | 2,231 | 226 | 83 | 1,922 | 86 |
| | Jan. 14-30, 1918.. | 7.20 | 1.05 | 6.15 | 85 | 1,472 | 152 | 68 | 1,252 | 85 |
| Mon... | Normal diet: | | | | | | | | | |
| | Oct. 1-4, 1917... | 15.67 | 1.59 | 14.08 | 90 | 3,406 | 148 | 103 | 3,155 | 93 |
| | Reduced diet: | | | | | | | | | |
| | Oct. 8-12, 1917.. | 12.40 | 1.22 | 11.18 | 90 | 2,328 | 135 | 95 | 2,098 | 90 |
| | Oct. 17-21, 1917.. | 11.38 | 1.24 | 10.14 | 89 | 2,053 | 162 | 92 | 1,799 | 88 |
| | Oct. 31-Nov. 4, 1917.......... | 9.50 | 0.98 | 8.52 | 90 | 1,772 | 126 | 91 | 1,555 | 88 |
| | Nov. 12-18, 1917.. | 9.97 | 1.33 | 8.64 | 87 | 1,832 | 170 | 89 | 1,573 | 86 |
| | Dec. 10-15, 1917.. | 13.92 | 2.14 | 11.78 | 85 | 3,008 | 269 | 85 | 2,649 | 88 |
| | Jan. 14-30, 1918.. | 12.02 | 1.55 | 10.47 | 87 | 2,246 | 188 | 88 | 1,970 | 88 |

TABLE 37.—*Nitrogen utilized and energy available from food in digestion periods—Squad A*—continued.

The indigestible bran in the diet unquestionably raised perceptibly the true undigested food material in the feces, and undoubtedly accounts, in part at least, for the low value for available energy noted with some of these men. And yet it is a fact that, using the two illustrations cited in discussing the nitrogen data, *Gar* and *Mon* on December 10 to 15, when the energy of the food with each subject was about 3,000 calories, there is actually a slightly larger value for available energy in the case of *Mon*, although *Gar* had no bran and *Mon* had 168 grams. While this discrepancy is strikingly opposed to the general belief that the presence of bran in the diet would tend to lower the available energy, and one must realize that, after all, a relatively small proportion of bran is indigestible,[1] nevertheless bran was in most instances an added food and contained a definite amount of unhydrolyzable material. It would thus normally be expected to lower the energy available. In practically all studies on reduced diet low values for available energy are found. Those noted here are well within normal limits and we have no reason to question the influence of the restricted diet upon the digestive processes of these men.

One great difficulty, encountered in this research, was the tendency for the reduced diet to produce constipation, this making the separation of feces difficult. With *Pec*, whose abnormal defecation has been commented on frequently in this report, no accurate separation could be obtained between November 29 and December 10, although three or four attempts were made, and only approximate values are recorded in table 55. (See p. 334.)

### DIGESTION EXPERIMENT WITH SQUAD B ON GREATLY REDUCED DIET.

Examining the data in table 37, we find that the energy of the food per day with Squad A averaged not far from 2,000 calories after the first week. With Squad B, it will be recalled, the energy of the food was cut down on the average to not far from 1,500 calories, and it was possible so to adjust the food intake that practically all 12 men received the same amounts of energy and nitrogen. The digestion period extended from January 15 to 23 (nearly twice as long as most of the digestion periods with Squad A). This long period gave an admirable opportunity for a satisfactory separation and for a study as to what proportion of nitrogen and total energy will appear in the feces when identically the same amounts of food materials are passed through 12 different digestive tracts. The data for Squad B are given in table 38, from which it can be seen that the nitrogen per day in the food varied only from 7.34 grams to 8.54 grams, with an average of 8.21 grams. The nitrogen in the feces varied from 0.53 gram to 1.40 grams, with an average of 0.89 gram. It is perhaps of significance that the

[1] Street, Conn. Agr. Expt. Sta. Ann. Rep., 1914, p. 243.

TABLE 38.—*Nitrogen utilized and energy available from food in digestion period with reduced diet—Squad B.*

| Date and subject. | Nitrogen per day— | | Nitrogen utilized. | | Energy per day— | | | Net energy. | |
|---|---|---|---|---|---|---|---|---|---|
| | (*a*) In food. | (*b*) In feces. | (*c*) Total (*a*-*b*). | (*d*) Per cent $\frac{(c \times 100)}{a}$. | (*e*) In food. | (*f*) In feces. | (*g*) In urine. | (*h*) Total [*e*−(*f*+*g*)] | (*i*) Per cent $\frac{(h \times 100)}{e}$ |
| Jan. 15–23, 1918: | *gm.* | *gm.* | *gm.* | | *cals.* | *cals.* | *cals.* | *cals.* | |
| Fis. | 8.32 | 1.40 | 6.92 | 83 | 1,550 | 145 | 78 | 1,327 | 86 |
| Har. | 7.99 | 0.74 | 7.25 | 91 | 1,488 | 96 | 88 | 1,304 | 88 |
| How. | 8.21 | 0.84 | 7.37 | 90 | 1,535 | 110 | 91 | 1,334 | 87 |
| Ham. | 7.34 | 0.53 | 6.81 | 93 | 1,433 | 79 | 87 | 1,267 | 88 |
| Kim. | 8.49 | 0.88 | 7.61 | 90 | 1,586 | 120 | 73 | 1,393 | 88 |
| Lon. | 8.23 | 0.63 | 7.60 | 92 | 1,535 | 91 | 79 | 1,365 | 89 |
| Sch. | 8.32 | 0.88 | 7.44 | 89 | 1,556 | 117 | 79 | 1,360 | 87 |
| Liv. | 8.32 | 0.68 | 7.64 | 92 | 1,546 | 108 | 92 | 1,346 | 87 |
| Sne. | 8.28 | 0.99 | 7.29 | 88 | 1,543 | 116 | 84 | 1,343 | 87 |
| Tho. | 8.32 | 1.20 | 7.12 | 86 | 1,551 | 138 | 86 | 1,327 | 86 |
| Van. | 8.15 | 0.99 | 7.16 | 88 | 1,528 | 126 | 82 | 1,320 | 86 |
| Wil. | 8.54 | 0.92 | 7.62 | 89 | 1,556 | 132 | 83 | 1,341 | 86 |
| Average.. | 8.21 | 0.89 | 7.32 | 89 | 1,534 | 115 | 84 | 1,336 | 87 |

lowest value (0.53) appeared with *Ham*, who likewise had the lowest nitrogen intake. The so-called digestible nitrogen ranged from 6.81 to 7.64 grams, with an average of 7.32 grams. The nitrogen utilized varied only from 83 to 93 per cent, with an average of 89 per cent.

Special attention should be given to the fecal nitrogen, for we have here conditions which are exactly comparable to those of Professor Chittenden's earlier research.[1] In the 6-day digestion period with Professor Chittenden's soldiers from January 12 to 17, 1904, an average of 49.4 grams of nitrogen was ingested by each subject, while the nitrogen in feces varied from 4.45 to 12.10 grams, with wide variations from the average (8.46 grams) in a majority of cases. Similar irregularities were noted in the digestion period from February 29 to March 6, 1904, and likewise from March 28 to April 1, 1904, although in this latter period the agreement was much closer. These experiments of Chittenden strongly suggest a disturbance of digestion with low diet, and it is difficult to account for the irregularity of the values. With our squad of 12 men such abnormalities did not appear, even though the nitrogen intakes were actually somewhat lower than those in Professor Chittenden's study and in all probability the caloric requirements were somewhat similar. It thus can be stated that with a group of college students on a very greatly reduced diet, disturbances in the proportion of nitrogen utilized were not found. The availability of the energy was not far from that found with Squad A,

[1] Chittenden, Physiological economy in nutrition, New York, 1907 (first issue, 1904), p. 131; also, in this connection, Benedict, Am. Journ. Physiol., 1906, 16, p. 420.

being on the average 87 per cent. The agreement among the men was remarkably constant, the widest variation being from 86 to 89 per cent. These men used on the average 25 grams of bran per day. The uniformity of the figures, both for nitrogen and energy, indicate that with a group of 12 men the same amount of food passing through 12 different digestive tracts results in a strikingly uniform degree of absorption, even when an extraordinarily low diet is being taken.

## URINE.

The collection of the entire 24-hour amount of urine from 12 or more subjects for a period of several months was for the most part very successfully carried out for Squad A, with the kind cooperation of these men. We have full data for these specimens of the volume, specific gravity, and total nitrogen. Obviously the most important factor is the total nitrogen. The nitrogen data appear in several places in this report, but it hardly seems justifiable to print the entire records of the specific gravity and the volume. We content ourselves, therefore, with giving a typical specimen of the urine records. (See table 39.) This shows the statistics for *Gul*, who collected the urine for almost every day of the entire experimental period, *i. e.*, September 27, 1917, to February 2, 1918. Since this subject remained at Springfield throughout the Christmas vacation, the records also include these days.

### STATISTICAL RECORDS OF URINE FOR SQUAD A.

The influence of restricted diet upon the volume of urine is typically shown in table 39. With *Bro*, *Can*, *Gar*, *Gul*, *Mon*, *Pea*, *Pec*, and *Vea*, the volume of urine was materially reduced as a result of the restricted diet, but with *Kon*, *Moy*, and *Spe* no effect on the volume of urine was noted. With a single subject (*Tom*) there was a distinct tendency for the volume of urine to increase, but it did not exceed the normal limits. Occasionally very low volumes were found as, for example, those with *Gul*, on January 17–18, 18–19, and 20–21. The largest volumes were consistently voided by *Can*, who had the largest body weight and who made a practice of drinking unusually large amounts of water. Even in his case, however, the volume did not exceed the normal amount.

The specific gravity has only a secondary interest in that it gives a rough indication of the amount of total solids, and incidentally, the amount of total nitrogen. With many of the subjects the specific gravity tended to increase, this being true of *Bro*, *Gul*, *Mon*, *Pea*, *Pec*, and *Vea*. With *Can*, *Kon*, *Gar*, *Moy*, and *Tom* no consistent change in the specific gravity was observed. With *Spe* there was a tendency for the specific gravity to become reduced. The general picture is that outlined in table 39 which indicates a tendency for the specific gravity to increase with the reduction in diet.

TABLE 39.—*Statistics of urine for Gul, Squad A.*

| Date. | Specific gravity. | Volume.[1] | Total nitrogen. |
|---|---|---|---|
| 1917. | | | |
| Normal diet: | | *c.c.* | *gm.* |
| Sept. 27–28 | ........ | 1,655 | 10.31 |
| Sept. 28–29 | ........ | 1,505 | 10.17 |
| Sept. 29–30 | ........ | 1,145 | 9.44 |
| Oct. 1– 2 | ........ | 1,010 | 12.97 |
| Oct. 2– 3 | 1.023 | 1,225 | 12.47 |
| Oct. 3– 4 | 1.024 | 1,190 | 12.35 |
| Reduced diet: | | | |
| Oct. 4– 5 | 1.017 | 1,580 | 12.31 |
| Oct. 5– 6 | 1.012 | 2,050 | 11.46 |
| Oct. 6– 7 | 1.016 | 1,660 | 10.30 |
| Oct. 7– 8 | 1.013 | 2,025 | 10.02 |
| Oct. 8– 9 | 1.019 | 1,420 | 12.16 |
| Oct. 9–10 | 1.019 | 1,950 | ........ |
| Oct. 10–11 | 1.015 | 2,095 | 12.94 |
| Oct. 11–12 | 1.020 | 1,235 | 11.75 |
| Oct. 12–13 | 1.018 | 1,560 | 12.73 |
| Oct. 13–14 | ........ | 1,095 | 11.11 |
| Oct. 15–16 | 1.013 | 1,570 | 9.47 |
| Oct. 16–17 | 1.023 | 1,175 | 13.26 |
| Oct. 17–18 | 1.015 | 1,560 | 12.40 |
| Oct. 18–19 | 1.024 | 1,115 | 13.71 |
| Oct. 19–20 | 1.024 | 1,000 | 11.31 |
| Oct. 20–21 | 1.023 | 1,140 | 12.01 |
| Oct. 21–22 | 1.024 | 820 | 8.86 |
| Oct. 22–23 | 1.016 | 1,270 | 10.62 |
| Oct. 23–24 | 1.018 | 1,490 | 10.98 |
| Oct. 24–25 | 1.025 | 1,385 | 12.21 |
| Oct. 25–26 | 1.027 | 735 | 9.78 |
| Oct. 26–27 | 1.031 | 600 | 9.33 |
| Oct. 27–28 | 1.031 | 675 | 10.53 |
| Oct. 29–30 | 1.026 | 990 | 9.92 |
| Oct. 30–31 | 1.028 | 1,035 | 11.96 |
| Oct. 31–Nov. 1 | 1.027 | 770 | 10.90 |
| Nov. 1– 2 | 1.028 | 930 | 11.52 |
| Nov. 2– 3 | 1.031 | 860 | 11.25 |
| Nov. 4– 5 | 1.030 | 760 | 10.21 |
| Nov. 5– 6 | 1.029 | 895 | 10.98 |
| Nov. 6– 7 | 1.029 | 925 | 9.85 |
| Nov. 7– 8 | 1.038 | 690 | 9.25 |
| Nov. 8– 9 | 1.029 | 830 | 9.39 |
| Nov. 9–10 | 1.030 | 580 | 6.98 |
| Nov. 10–11 | 1.032 | 540 | 9.11 |
| Nov. 12–13 | 1.030 | 890 | 8.60 |
| Nov. 13–14 | 1.031 | 810 | 9.52 |
| Nov. 14–15 | 1.032 | 825 | 11.39 |
| Nov. 15–16 | 1.037 | 680 | 11.04 |
| Nov. 16–17 | 1.030 | 720 | 10.90 |
| Nov. 17–18 | 1.031 | 760 | 10.87 |
| Nov. 18–19 | 1.030 | 720 | 9.35 |
| Nov. 19–20 | 1.028 | 1,110 | 10.51 |
| Nov. 20–21 | 1.030 | 895 | 9.25 |
| Nov. 21–22 | 1.031 | 885 | 10.01 |
| Nov. 22–23 | 1.031 | 810 | 8.99 |
| Nov. 23–24 | 1.038 | 385 | 6.13 |
| Nov. 24–25 | 1.021 | 860 | 11.00 |
| Nov. 26–27 | 1.033 | 675 | 7.48 |
| Nov. 27–28 | 1.041 | 705 | 9.56 |
| Nov. 28–29 | 1.037 | 630 | 7.16 |
| Nov. 29–30 | 1.039 | 470 | 5.59 |
| Dec. 1– 2 | 1.040 | 455 | 3.90 |
| Dec. 2– 3 | 1.035 | 570 | 4.70 |
| Dec. 3– 4 | 1.035 | 380 | 5.51 |
| 1917. | | | |
| Reduced diet: | | *c.c.* | *gm.* |
| Dec. 4– 5 | 1.041 | 780 | 13.37 |
| Dec. 5– 6 | 1.034 | 775 | ........ |
| Dec. 6– 7 | 1.033 | 670 | 8.86 |
| Dec. 7– 8 | 1.038 | 840 | 10.74 |
| Dec. 8– 9 | 1.030 | 710 | 9.22 |
| Dec. 10–11 | 1.032 | 975 | 9.11 |
| Dec. 11–12 | 1.034 | 840 | 9.53 |
| Dec. 12–13 | 1.038 | 800 | 11.28 |
| Dec. 13–14 | 1.037 | 785 | 11.92 |
| Dec. 14–15 | 1.029 | 820 | 10.07 |
| Dec. 15–16 | 1.027 | 970 | 9.45 |
| Dec. 16–17 | 1.031 | 665 | ........ |
| Dec. 17–18 | 1.040 | 870 | 12.10 |
| Dec. 18–19 | 1.016 | 1,575 | 13.01 |
| Dec. 19–20 | 1.022 | 820 | 10.35 |
| Dec. 20–21 | 1.040 | 620 | 8.73 |
| Dec. 21–22 | 1.041 | 820 | 7.58 |
| Dec. 22–23 | 1.043 | 740 | 7.92 |
| Dec. 23–24 | 1.036 | 820 | 9.75 |
| Dec. 24–25 | 1.035 | 1,300 | 13.56 |
| Dec. 25–26 | 1.040 | 1,240 | 14.66 |
| Dec. 26–27 | 1.040 | 1,020 | 11.54 |
| Dec. 27–28 | 1.040 | 840 | 8.63 |
| Dec. 28–29 | 1.037 | 820 | 9.85 |
| Dec. 29–30 | 1.031 | 1,420 | 11.20 |
| Dec. 30–31 | 1.036 | 1,020 | 10.49 |
| Dec. 31–Jan. 1 | 1.040 | 820 | 9.02 |
| 1918. | | | |
| Jan. 1– 2 | 1.039 | 740 | 8.92 |
| Jan. 2– 3 | 1.043 | 520 | 7.26 |
| Jan. 3– 4 | 1.042 | 920 | 13.48 |
| Jan. 4– 5 | 1.040 | 680 | 8.28 |
| Jan. 5– 6 | 1.039 | 540 | 7.03 |
| Jan. 6– 7 | 1.036 | 420 | 7.23 |
| Jan. 7– 8 | 1.032 | 540 | 10.24 |
| Jan. 8– 9 | 1.033 | 630 | 10.27 |
| Jan. 9–10 | 1.029 | 860 | 9.90 |
| Jan. 10–11 | 1.030 | 650 | 9.31 |
| Jan. 11–12 | 1.020 | 955 | 9.39 |
| Jan. 12–13 | 1.026 | 700 | 8.71 |
| Jan. 13–14 | 1.031 | 625 | 6.53 |
| Jan. 14–15 | 1.029 | 970 | 7.99 |
| Jan. 15–16 | 1.031 | 575 | 7.47 |
| Jan. 16–17 | 1.031 | 540 | 7.74 |
| Jan. 17–18 | 1.027 | 395 | 6.08 |
| Jan. 18–19 | 1.037 | 390 | 9.06 |
| Jan. 19–20 | 1.034 | 470 | 10.57 |
| Jan. 20–21 | 1.035 | 420 | 8.31 |
| Jan. 21–22 | 1.031 | 540 | 7.99 |
| Jan. 22–23 | 1.034 | 490 | 8.11 |
| Jan. 23–24 | 1.023 | 900 | 8.02 |
| Jan. 24–25 | 1.022 | 705 | 7.71 |
| Jan. 25–26 | 1.018 | 1,280 | 9.57 |
| Jan. 26–27 | 1.013 | 1,560 | 9.85 |
| Jan. 27–28 | 1.034 | 1,050 | 8.62 |
| Jan. 28–29 | 1.033 | 930 | 9.27 |
| Jan. 29–30 | 1.012 | 1,755 | 8.93 |
| Jan. 30–31 | 1.019 | 1,355 | 8.86 |
| Jan. 31–Feb. 1 | 1.021 | 1,390 | 7.95 |
| Feb. 1– 2 | 1.031 | 990 | 8.28 |
| Feb. 2– 3 | 1.025 | 890 | 6.69 |

[1] Volumes represent mainly 24 hour samples; a number were computed to basis of 24 hours from samples covering 22½ to 25½ hours. In two instances the samples were for 21½ and 26 hours respectively.

The total nitrogen excretion may first be considered simply as an index of the excretion of organic material. It can be seen from table 39 that with *Gul* the nitrogen excretion varied considerably from day to day. The maximum amount recorded for this subject on any day was 14.66 grams during the Christmas vacation; the minimum amount was the extraordinarily small quantity of 3.90 grams on December 1–2. In the beginning of the experiment there was considerable irregularity in the amount of nitrogen excreted, with a tendency for lower values to obtain subsequent to November 22. Yet there appears to be no definite correlation between the volume of urine, the specific gravity, and the total nitrogen excretion, nor do the other subjects show an approximation to regularity in such relationship. The nitrogen data for the other subjects will, however, be given in subsequent tables and discussed in that connection.

The general conclusion, therefore, which may be drawn from the urinary excretion of these subjects is that the reduced diet has a distinct tendency to lower somewhat the volume of urine and likewise a corresponding tendency to increase to some extent the specific gravity. This is more or less to be inferred from the fact that there was no profound alteration in the total amount of nitrogen excreted, and hence the smaller volume of urine was somewhat more concentrated. Little, if any, satisfactory discussion can be introduced here as to the fact that the lower volumes require somewhat less work of the kidneys, for it may be questioned whether or not the decrease in the work of excretion due to the smaller volumes would not in large part be compensated by the somewhat increased concentration of the urine. In any event the change is not sufficient to consider that this would have a material effect upon the general urinary output of these subjects, so far as specific gravity and the volume of urine are concerned.

### NITROGEN INTAKE AND OUTPUT OF SQUAD A.

While the statistics for *Gul* show no consistently lower output of nitrogen, save perhaps subsequent to November 22, nevertheless even this change was not profound, and it seems advisable to consider how the low diet affected the squad as a whole. It has already been shown that the intake of nitrogen was not in all cases alike. In general, however, the average intake was not far from the same for the entire squad, both in total calories and in total nitrogen. This is shown more in detail in certain other tables.[1]

Although this is not the specific place to discuss the relationship between the intake and output of nitrogen, with special reference to the nitrogen balance, several features of the first 12 days of the experiment justify our reproducing here the figures for the total nitrogen in urine for this period and likewise for a period of 12 days from

[1] See tables 46 to 58, pp. 312 to 341.

December 5 to 18, when the squad was essentially on maintenance diet at the lower level. (See tables 41 and 43.) The nitrogen in the food for the first 10 days in the experiment and for December 5 to 18 are also given in tables 40 and 42. Considering the nitrogen in the urine during the first 12 days of the experiment (table 41), we find that fluctuations occur not only between different men, but that the same man shows differences from day to day. The lowest nitrogen output is almost invariably shown by *Tom*. The total nitrogen output per day for the 12 men averages not far from 145 to 150 grams for this period.

TABLE 40.—*Total nitrogen in food during first 10 days of experiment—Squad A.*

| Subject. | Normal diet.[1] | | | Reduced diet. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Oct. 1. | Oct. 2. | Oct. 3. | Oct. 4. | Oct. 5. | Oct. 6. | Oct. 7. | Oct. 8. | Oct. 9. | Oct. 10. |
| | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* |
| Bro.... | 14.63 | 14.93 | 15.54 | 10.46 | 11.85 | 10.87 | 9.24 | 13.98 | 12.36 | 12.35 |
| Can.... | 15.59 | 14.93 | 15.54 | 10.46 | 11.85 | 10.87 | 9.26 | 13.82 | 12.21 | 12.19 |
| Fre..... | 15.53 | 14.93 | 15.54 | 10.46 | 11.85 | 10.87 | 9.49 | 13.82 | 12.25 | 11.52 |
| Gar.... | 17.49 | 14.61 | 15.54 | 10.46 | 11.85 | 10.87 | 9.14 | 13.67 | 12.21 | 11.83 |
| Gul.... | 16.25 | 14.93 | 15.54 | 10.46 | 11.85 | 10.87 | 9.67 | 13.82 | 12.21 | 12.50 |
| Mon.... | 16.55 | 14.93 | 15.54 | 10.46 | 11.85 | 10.87 | 10.00 | 13.82 | 12.21 | 12.30 |
| Moy... | 14.98 | 14.93 | 15.54 | 10.46 | 11.85 | 10.87 | 8.61 | 13.82 | 12.05 | 12.19 |
| Pea.... | 15.94 | 14.93 | 15.54 | 10.46 | 11.85 | 10.87 | 9.21 | 13.82 | 12.21 | 12.03 |
| Pec.... | 16.51 | 14.93 | 15.54 | 10.46 | 11.85 | 10.87 | 9.65 | 13.98 | 12.21 | 13.13 |
| Spe.... | 17.79 | 14.93 | 15.54 | 10.46 | 11.85 | 10.87 | 9.65 | 13.82 | 12.21 | 12.19 |
| Tom... | 14.63 | 14.93 | 15.17 | 10.46 | 11.85 | 10.87 | 8.89 | 13.82 | 12.05 | 12.35 |
| Vea.... | 16.25 | 14.93 | 15.54 | 10.46 | 11.85 | 10.87 | 9.14 | 13.67 | 12.05 | 11.52 |
| Av.. | 16.01 | 14.90 | 15.51 | 10.46 | 11.85 | 10.87 | 9.33 | 13.82 | 12.19 | 12.18 |

[1] Samples were not obtained of the diet on September 28 and 29.

TABLE 41.—*Total nitrogen in urine per 24 hours during first 12 days of experiment—Squad A.*

| Subject. | Normal diet. | | | | | Reduced diet. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sept. 28. | Sept. 29. | Oct. 1. | Oct. 2. | Oct. 3. | Oct. 4. | Oct. 5. | Oct. 6. | Oct. 7. | Oct. 8. | Oct. 9. | Oct. 10. |
| | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* |
| Bro.. | 9.98 | 9.90 | 11.72 | 12.38 | 11.42 | 10.82 | 11.77 | 11.25 | 11.35 | 10.15 | 13.75 | 11.59 |
| Can.. | 13.36 | 11.50 | 13.60 | 13.27 | 14.41 | 13.46 | 13.00 | 13.34 | 13.65 | 15.24 | 13.50 | 14.41 |
| Fre.. | 12.40 | 10.40 | 12.02 | 14.29 | 12.40 | 11.53 | 11.86 | 11.66 | 12.53 | 12.16 | 10.34 | 12.16 |
| Gar.. | 14.45 | 11.96 | 14.50 | 13.56 | 14.03 | 11.71 | 10.71 | 11.43 | 11.33 | 12.22 | 12.56 | 11.76 |
| Gul.. | 10.17 | 8.97 | 12.97 | 12.47 | 12.35 | 12.31 | 11.46 | 10.09 | 10.02 | 12.16 | ...... | 12.94 |
| Mon. | 11.66 | 8.98 | 13.85 | 7.30 | 17.38 | 7.03 | 12.59 | 14.19 | 12.89 | 11.64 | 11.10 | 13.49 |
| Moy. | 10.06 | 6.28 | 10.97 | 13.36 | 12.64 | 12.65 | 11.41 | 12.18 | 10.27 | 10.57 | 11.43 | 11.57 |
| Pea.. | 14.18 | 11.77 | 12.21 | 13.80 | 13.91 | 14.53 | 14.37 | 11.58 | 13.22 | 14.93 | 15.53 | 14.83 |
| Pec.. | 15.62 | 13.41 | 12.89 | 14.64 | 11.54 | 13.44 | 13.44 | 11.80 | 15.13 | 12.15 | 13.94 | 15.18 |
| Spe.. | 14.81 | 14.56 | 13.85 | 14.70 | 14.49 | 11.92 | 13.69 | 12.47 | 10.38 | 12.93 | 12.88 | 12.99 |
| Tom. | 5.30 | 5.87 | 8.78 | 9.98 | 10.22 | 9.24 | 9.57 | 9.90 | 9.14 | 9.25 | 10.73 | 11.04 |
| Vea.. | 17.21 | 12.70 | 15.24 | 13.41 | 13.00 | 12.82 | 10.38 | 10.82 | 11.31 | 11.18 | 12.21 | 11.51 |
| Av.. | 12.43 | 10.53 | 12.72 | 12.76 | 13.15 | 11.79 | 12.02 | 11.73 | 11.77 | 12.05 | 12.54 | 12.79 |

TABLE 42.—*Total nitrogen in food during 13 typical days after long diet restriction—Squad A.*

| Subject. | Dec. 5. | Dec. 6. | Dec. 7. | Dec. 8. | Dec. 10. | Dec. 11. | Dec. 12. | Dec. 13. | Dec. 14. | Dec. 15. | Dec. 16. | Dec. 17. | Dec. 18. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* |
| Bro........ | 8.97 | 9.48 | 7.69 | 9.75 | 8.23 | 14.63 | 11.89 | 9.89 | 8.97 | 10.98 | 9.64 | 14.71 | 13.44 |
| Can........ | 10.97 | 11.61 | 9.14 | 11.95 | 11.33 | 17.04 | 14.70 | 12.64 | 12.22 | 18.31 | 12.74 | 14.34 | 14.36 |
| Kon........ | 8.81 | 8.54 | 6.57 | 7.86 | 7.76 | 10.12 | 11.39 | 7.86 | 8.17 | 10.51 | 9.17 | 11.55 | 10.50 |
| Gar........ | 8.62 | 8.88 | 8.65 | 11.46 | 10.35 | 16.73 | 13.90 | 13.26 | 11.74 | 18.31 | 12.74 | 13.96 | 13.06 |
| Gul........ | 10.02 | 10.77 | 8.45 | 8.80 | 9.95 | 10.43 | 12.02 | 10.83 | 8.97 | 10.98 | 10.02 | 12.76 | 11.71 |
| Mon........ | 10.02 | 10.81 | 9.90 | 11.46 | 11.60 | 17.67 | 15.01 | 13.10 | 12.22 | 13.32 | 12.92 | 15.63 | 15.11 |
| Moy........ | 9.56 | 9.67 | 7.38 | 8.82 | 8.70 | 14.63 | 14.03 | 10.02 | 8.48 | 10.98 | 9.64 | 14.34 | 14.19 |
| Pea........ | 11.75 | 12.55 | 9.90 | 11.28 | 11.75 | 14.14 | 15.01 | 13.10 | 12.22 | 13.80 | 13.40 | 16.01 | 15.11 |
| Pec........ | 9.75 | 10.41 | 8.45 | 8.64 | 9.63 | 10.75 | 12.02 | 10.34 | 8.48 | 10.51 | 9.55 | 12.76 | 11.71 |
| Spe........ | 12.22 | 12.08 | 7.84 | 9.32 | 9.67 | 17.35 | 14.39 | 7.79 | ...... | ...... | ...... | ...... | ...... |
| Tom........ | 8.19 | 8.54 | 5.23 | 7.86 | 5.16 | 6.52 | 7.44 | 9.40 | 8.17 | 10.03 | 8.13 | 11.73 | 10.87 |
| Vea........ | 8.19 | 8.70 | 6.75 | 8.51 | 8.07 | 9.81 | 11.24 | 9.40 | 8.48 | 10.51 | 8.61 | 10.90 | 10.04 |
| Av...... | 9.76 | 10.17 | 8.00 | 9.64 | 9.35 | 13.32 | 12.75 | 10.64 | 9.83 | 12.57 | 10.60 | 13.52 | 12.74 |

TABLE 43.—*Total nitrogen in urine per 24 hours during 12 typical days after long restricted diet—Squad A.*

| Subject. | Dec. 5. | Dec. 6. | Dec. 7. | Dec. 8. | Dec. 10. | Dec. 11. | Dec. 12. | Dec. 13. | Dec. 14. | Dec. 15. | Dec. 17[1]. | Dec. 18. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* |
| Bro.. | 10.33 | ...... | 9.10 | 9.89 | 9.96 | 10.34 | 12.16 | 10.64 | 10.47 | 9.03 | ...... | 13.21 |
| Can.. | 10.86 | 12.22 | 10.39 | 11.76 | 9.54 | ...... | 12.15 | 11.38 | 11.31 | 11.18 | ...... | 13.54 |
| Kon. | 15.68 | 17.35 | 13.18 | 14.15 | 10.31 | 11.03 | 14.03 | 14.67 | 9.88 | 11.54 | 12.75 | 11.99 |
| Gar.. | 11.21 | 9.58 | 11.87 | 9.05 | 10.59 | 10.04 | 11.08 | 10.41 | 9.02 | 8.71 | 11.40 | 13.36 |
| Gul.. | ...... | 8.86 | 10.74 | 8.85 | 9.11 | 9.53 | 11.28 | 11.92 | 10.07 | 9.45 | 12.10 | 13.01 |
| Mon. | 12.55 | 12.59 | 11.67 | 12.18 | 10.17 | 11.65 | 12.33 | 11.71 | 7.31 | 13.21 | 10.36 | 13.01 |
| Moy. | 11.59 | 10.58 | 9.86 | 10.07 | 8.84 | 10.83 | 10.59 | 11.27 | ...... | 9.37 | 11.75 | 13.29 |
| Pea.. | ...... | 10.91 | 11.35 | 9.29 | 11.21 | 10.82 | 11.88 | 12.19 | 12.22 | 10.98 | 12.28 | 13.82 |
| Pec.. | 12.40 | 11.55 | 11.35 | 10.17 | 13.28 | 9.67 | 10.90 | 11.51 | 10.21 | ...... | 10.76 | 11.67 |
| Spe.. | 14.81 | 11.95 | 10.83 | 11.66 | 8.79 | 13.11 | 9.40 | 12.31 | ...... | ...... | ...... | ...... |
| Tom. | 6.92 | 8.71 | 6.47 | 7.54 | 8.93 | 6.41 | 7.78 | 9.53 | 8.17 | ...... | 10.20 | 6.27 |
| Vea.. | 9.72 | 10.79 | 11.61 | 10.26 | 9.44 | 8.60 | 11.68 | 12.50 | 9.37 | ...... | 10.98 | 11.12 |
| Av.. | 11.61 | 11.37 | 10.70 | 10.41 | 10.01 | 10.18 | 11.27 | 11.67 | 9.80 | 10.43 | 11.40 | 12.21 |

[1] The urine samples for December 16 were frozen in transit, and it was thus impossible to obtain the nitrogen output for this day.

The total nitrogen intake at this time (table 40) is of special interest, since it gives us an indication of the first reduction in diet, which took place on October 4. Prior to this, although the subjects were requested to eat as freely as they normally would, we find that the nitrogen intake was surprisingly uniform with all men on October 1, 2, and 3, when the men were on an unrestricted diet. It is clear that any difference in intake for these 10 days must have been in the non-protein food materials, for these men had essentially the same protein intake. Indeed, the daily intake for the individual men is almost exactly the same save on October 1. This comparison of data presents an interesting physiological study, however, inasmuch as we have

18, inclusive, when the subjects had approximately a maintenance ration, at least so far as caloric intake was concerned, is shown in table 43. The average nitrogen excretion for the entire 12 days was 10.92 grams per man per day. The variations in daily averages are somewhat larger than in the earlier part of the experiment, for here they range from 9.80 grams on December 14 to a maximum of 12.21 grams 3 days later, but are reasonably uniform, the average value, 10.92 grams, being a little over 1 gram less than the average value found for the first 12 days of the research. In other words, we see clearly that we deal with no large variations in the daily excretion of nitrogen, considering the squad as a whole.

The average nitrogen intake in the food from October 1 to 10 inclusive (table 40) was 12.71 grams, although on 3 days high values were observed. The average of the first 3 days is 15.47 grams; the average of the last 7 days is 11.53 grams. The irregularity of the intake of nitrogen, even after the curtailment in the diet began, is shown by the fact that on October 7 the average nitrogen intake was 9.33 grams and on the next day it was 4.5 grams larger. Notwithstanding these relatively large variations in the nitrogen intake, the average urinary nitrogen (table 41) remained singularly constant throughout this period.

The nitrogen in the food intake in the period from December 5 to 18 is shown in table 42. Considerable variation is also found in these amounts, the daily averages ranging from the low value of 8 grams on December 7 to a maximum of 13.52 grams on December 17. The minimum average of 8 grams is 3 grams lower than the general average of 10.99 grams, and the maximum average is 2.5 grams higher. Turning again to the urinary output during this period (table 43), it is perhaps surprising that we find a greater degree of uniformity obtaining, for while there are variations, they do not approximate in size the variations found in the food intake. The fact that the average nitrogen intake in the period of December 5 to December 18 is 10.99 grams and the average nitrogen output in the urine is 10.92 grams shows that these men were not in nitrogen equilibrium, for no allowance has been made for fecal nitrogen or for losses through the skin. So while these subjects were in weight equilibrium, they were not as yet in nitrogen equilibrium. Mention is made of this here to emphasize the fact that while nitrogen equilibrium may suggest weight equilibrium, the reverse is by no means true. (See page 353.)

The inspection of the fragmentary evidence of the nitrogen intake and output, as shown in these sections of the food and urine tables for the two periods of the experiment, makes it necessary to present in abstract form the average nitrogen in the food and urine per man per day for the entire experimental period, for the relationship between them is an important one. Tables 40 to 43, inclusive, give not only the average values, but likewise the values for each man, and permit a study

remained singularly constant for the squad as a whole throughout practically the entire period, aside from the general slight change of 1 gram in level in the periods indicated above. The nitrogen in urine in the last week in October is essentially on the same level as the nitrogen in urine in the last week in January.

TABLE 44.—*Total nitrogen in food and urine*[1]—*Squad A.*

[Average per man per day.]

| Date. | Total nitrogen in— | | Date. | Total nitrogen in— | | Date. | Total nitrogen in— | |
|---|---|---|---|---|---|---|---|---|
| | Food. | Urine. | | Food. | Urine. | | Food. | Urine. |
| 1917. | *gm.* | *gm.* | 1917. | *gm.* | *gm.* | 1917. | *gm.* | *gm.* |
| Normal diet: | | | Reduced diet: | | | Reduced diet: | | |
| Sept. 28–29.... | ....... | 12.43 | Nov. 5– 6.... | 9.26 | 10.98 | Dec. 15–16.... | 12.57 | 10.43 |
| Sept. 29–30.... | ....... | 10.53 | Nov. 6– 7.... | 8.65 | 10.56 | Dec. 16–17.... | 10.60 | ....... |
| Oct. 1– 2.... | 16.01 | 12.72 | Nov. 7– 8.... | 9.56 | 10.94 | Dec. 17–18.... | 13.52 | 11.40 |
| Oct. 2– 3.... | 14.90 | 12.76 | Nov. 8– 9.... | 7.21 | 10.25 | Dec. 18–19.... | 12.74 | 12.21 |
| Oct. 3– 4.... | 15.51 | 13.15 | Nov. 9–10.... | 7.90 | 9.17 | Dec. 19–20.... | 11.03 | 11.29 |
| Reduced diet: | | | Nov. 10–11.... | 8.93 | 11.21 | Christmas | | |
| Oct. 4– 5.... | 10.46 | 11.79 | Nov. 12–13.... | 7.94 | 9.33 | recess. | | |
| Oct. 5– 6.... | 11.85 | 12.02 | Nov. 13–14.... | 11.33 | 10.01 | 1918. | | |
| Oct. 6– 7.... | 10.87 | 11.73 | Nov. 14–15.... | 10.72 | 11.29 | Jan. 7– 8.... | 9.30 | 10.41 |
| Oct. 7– 8.... | 9.33 | 11.77 | Nov. 15–16.... | 8.04 | 11.09 | Jan. 8– 9.... | 10.53 | 9.99 |
| Oct. 8– 9.... | 13.82 | 12.05 | Nov. 16–17.... | 10.40 | 11.89 | Jan. 9–10.... | 9.30 | 11.22 |
| Oct. 9–10.... | 12.19 | 12.54 | Nov. 17–18.... | 8.93 | 11.05 | Jan. 10–11.... | 8.18 | 11.21 |
| Oct. 10–11.... | 12.18 | 12.79 | Nov. 18–19.... | 8.63 | 10.73 | Jan. 11–12.... | 8.68 | 10.38 |
| Oct. 11–12.... | 10.89 | 11.16 | Nov. 19–20.... | 11.55 | 10.59 | Jan. 12–13.... | 8.67 | 10.82 |
| Oct. 12–13.... | 11.85 | 11.91 | Nov. 20–21.... | 10.58 | 10.68 | Jan. 13–14.... | ....... | 11.27 |
| Oct. 13–14.... | 9.29 | 10.95 | Nov. 21–22.... | 8.96 | 10.03 | Jan. 14–15.... | 6.94 | 9.06 |
| Oct. 15–16.... | 10.86 | 11.10 | Nov. 22–23.... | 9.73 | 9.99 | Jan. 15–16.... | 7.07 | 7.90 |
| Oct. 16–17.... | 12.59 | 12.23 | Nov. 23–24.... | 9.38 | 9.04 | Jan. 16–17.... | 9.24 | 9.49 |
| Oct. 17–18.... | 9.97 | 11.82 | Nov. 24–25.... | 9.41 | 10.32 | Jan. 17–18.... | 8.02 | 9.72 |
| Oct. 18–19.... | 14.37 | 13.16 | Nov. 26–27.... | 10.81 | 8.93 | Jan. 18–19.... | 10.92 | 10.81 |
| Oct. 19–20.... | 9.92 | 11.38 | Nov. 27–28.... | 8.87 | 10.13 | Jan. 19–20.... | 9.28 | 10.57 |
| Oct. 20–21.... | 10.17 | 11.92 | Nov. 28–29.... | 7.34 | 10.79 | Jan. 20–21.... | 8.85 | 10.25 |
| Oct. 21–22.... | 9.54 | 10.53 | Nov. 29–30.... | ....... | 10.75 | Jan. 21–22.... | 9.06 | 9.63 |
| Oct. 22–23.... | 8.77 | 10.22 | Thanksgiving | | | Jan. 22–23.... | 10.93 | 10.63 |
| Oct. 23–24.... | 10.62 | 11.05 | recess. | | | Jan. 23–24.... | 9.63 | 10.72 |
| Oct. 24–25.... | 12.61 | 11.27 | Dec. 3– 4.... | 6.94 | 9.21 | Jan. 24–25.... | 9.89 | 9.87 |
| Oct. 25–26.... | 7.93 | 10.09 | Dec. 4– 5.... | 11.47 | 11.51 | Jan. 25–26.... | 10.09 | 9.66 |
| Oct. 26–27.... | 10.87 | 10.56 | Dec. 5– 6.... | 9.76 | 11.61 | Jan. 26–27.... | 10.06 | 10.89 |
| Oct. 27–28.... | 8.67 | 10.90 | Dec. 6– 7.... | 10.17 | 11.37 | Jan. 27–28.... | 8.80 | 11.47 |
| Oct. 29–30.... | 11.54 | 10.22 | Dec. 7– 8.... | 8.00 | 10.70 | Jan. 28–29.... | 11.84 | 10.21 |
| Oct. 30–31.... | 11.89 | 11.99 | Dec. 8– 9.... | 9.64 | 10.41 | Jan. 29–30.... | 14.12 | 10.68 |
| Oct. 31–Nov. 1. | 8.94 | 11.16 | Dec. 10–11.... | 9.35 | 10.01 | Jan. 30–31.... | 10.87 | 9.96 |
| Nov. 1– 2.... | 8.89 | 11.92 | Dec. 11–12.... | 13.32 | 10.18 | Jan. 31–Feb. 1. | 16.29 | 11.80 |
| Nov. 2– 3.... | 9.98 | 11.94 | Dec. 12–13.... | 12.75 | 11.27 | Feb. 1– 2.... | 14.74 | 11.78 |
| Nov. 3– 4.... | 8.45 | 11.43 | Dec. 13–14.... | 10.64 | 11.67 | Feb. 2– 3.... | 9.10 | 9.77 |
| Nov. 4– 5.... | 8.53 | 11.15 | Dec. 14–15.... | 9.83 | 9.80 | | | |

[1] The values in this table, except for January 13–14, represent only days when the diet was controlled and do not include the uncontrolled Sundays.

## NORMAL URINARY NITROGEN OF A GROUP OF COLLEGE STUDENTS.

Although the first 5 values for the urinary nitrogen in table 44, which are also shown in table 41, may be taken to indicate the normal nitrogen output for the group of 12 men when they were on unrestricted

TABLE 45.—*Nitrogen excretion of International Y. M. C. A. College students during periods with normal diet.*

| Subject. | Age. | Body-weight. | Height. | Nitrogen excretion on— Feb. 11–12. | Feb. 12–13. | Feb. 13–14. | Feb. 14–15. | Feb. 15–16. | Average. |
|---|---|---|---|---|---|---|---|---|---|
| | *yrs.* | *kg.* | *cm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* | *gm.* |
| Branin | 24 | 63 | 170 | 10.49 | 13.99 | 13.59 | 13.30 | 15.94 | 13.46 |
| Brown, I. E. | 27 | 77 | 178 | 12.61 | 18.13 | 18.70 | 16.82 | 19.26 | 17.10 |
| Davis | 22 | 67 | 178 | 11.49 | 14.18 | 12.49 | ....... | ....... | 12.72 |
| Dennis | 23 | 82 | 183 | 20.53 | 11.85 | 11.23 | 15.44 | 12.62 | 14.33 |
| Hodge | 22 | 72 | 180 | 14.02 | 12.28 | 11.31 | 12.13 | 15.15 | 12.98 |
| Landis | 22 | 70 | 170 | 9.33 | 13.54 | 14.09 | 13.08 | 14.84 | 12.98 |
| Lewis | 27 | 77 | 183 | 12.77 | 19.76 | 15.94 | 15.15 | 19.54 | 16.63 |
| Lyon | 21 | 73 | 174 | 15.66 | 18.73 | 14.49 | 13.07 | 13.81 | 15.15 |
| McKelvey | 24 | 68 | 173 | 13.21 | 14.37 | 14.38 | 14.50 | 12.76 | 13.84 |
| McKnight | 21 | 73 | 178 | 11.25 | 14.30 | 15.23 | 14.84 | 10.99 | 13.32 |
| Nickerson | 26 | 60 | 163 | 10.75 | 9.50 | 12.28 | ....... | 10.81 | 10.84 |
| Otto | 25 | 73 | 175 | 12.58 | 13.01 | 14.71 | 16.20 | 14.79 | 14.26 |
| Average | 24 | 71 | 175 | 12.89 | 14.47 | 14.04 | 14.45 | 14.59 | 13.97 |

| Subject. (Squad B.) | Nitrogen excretion on Jan. 7–8, 1918. Hours represented. | Amount. | Calculated to 24 hours. |
|---|---|---|---|
| | | *gm.* | *gm.* |
| Fis | 18 | 7.72 | 10.29 |
| Har | 16½ | 9.58 | 13.93 |
| How | 7½ | 5.75 | 18.40 |
| Ham | 23¾ | 14.80 | 14.96 |
| Kim | 17½ | 8.67 | 11.89 |
| Sch | 22¾ | 8.60 | 9.07 |
| Liv | 27 | 16.24 | 14.44 |
| Sne | 21¼ | 12.16 | 13.73 |
| Tho | 16½ | 9.03 | 13.13 |
| Van | 17½ | 7.68 | 10.53 |
| Wil | 20¼ | 11.99 | 14.21 |
| Average | ............ | ......... | 13.14 |

## STATISTICS OF URINE FOR SQUAD B ON REDUCED DIET.

Since the purpose of placing Squad B upon restricted diet was somewhat different from that for Squad A and the reduction in diet was very much greater, the statistics of urine for this squad are not given special treatment in this discussion. The values for the nitrogen per 24 hours in urine and the corresponding amounts of nitrogen in the food are given in the nitrogen balance tables 59 to 70 in a subsequent section. It is only necessary to point out at this time that an inspection of these tables shows that in spite of the great curtailment of nitrogen intake of nearly one-half, the average nitrogen

fidelity on the part of the men and the nitrogen in the urine determined. Thus, we have sufficient data with Squad A to indicate the general picture of the nitrogen balance throughout the entire 4 months. With Squad B the conditions were much more satisfactory from the experimental standpoint. The men were on the diet for a period of only 20 days, there were no days of uncontrolled diet, and the balance between the nitrogen intake and the nitrogen output may be definitely determined.

In any final summation of the nitrogen balance for the period of 4 months during which the experiment continued, the nitrogen intake during these unrestricted Sundays and the holiday periods must be taken into account. On 5 uncontrolled Sundays the men made reasonably close estimates of the food taken. These records are given with the computed energy and nitrogen content in table 34. It might be assumed that the amounts of nitrogen ingested on the uncontrolled Sundays could be taken as an index of the nitrogen intake on the Thanksgiving and Christmas holidays, but it is by no means certain that this would be a legitimate assumption. From the reports of the men regarding their dietetic habits during these vacations, it is clear that the high rate of nitrogen ingestion on the uncontrolled Sundays was by no means continued through the entire vacation periods. The fact that the men were morally obligated to return to college at or near their last recorded weight certainly acted as a deterring influence upon excessive consumption. It does not, therefore, seem justifiable to us to assume an average intake of 16.62 grams of nitrogen for each day not specifically noted in our tables between September 27 and February 3.

It may be seen, however, that any nitrogen balance which may be made without taking into consideration the nitrogen intake of these days will undoubtedly be defective in that the apparent intake of nitrogen will be perceptibly lower than the real intake. On the other hand, the record of the output of nitrogen when measured by the nitrogen of the urine and feces is also deficient in that the urinary and fecal analyses take no note of the loss through the skin, perspiration, epithelial débris, growth of hair and nails, etc. Evidence with regard to the loss through the skin with normal individuals has been somewhat extensively discussed elsewhere.[1] In this earlier study it was found that on the average with men during complete muscular rest, living a restricted life inside the respiration calorimeter, about 0.1 gram of nitrogen per 24 hours was excreted through the skin. During severe muscular work with free perspiration the experimental data showed that there may be as much as 0.22 gram of nitrogen excreted per hour. As may be seen from the record of the physical activity of the men in

[1] Benedict, Journ. Biol. Chem., 1906, 1, p. 263.

the low-diet research, they were by no means at rest. A large number of them indulged in severe physical exercise, such as gymnasium work and running. Although Professor Johnson reports that in the 5-minute bicycle riding period the men in Squad A perspired very rarely and very slightly as compared with the men in Squad B, who were on normal diet, nevertheless it is unquestionably true that the gymnastic work these men engaged in, and their occasional trips to the swimming-pool, would cause a considerable loss of cutaneous nitrogenous material.

Attempts have been made by various writers to estimate the loss through the skin and through the growth of hair and nails. Thus, Taylor[1] summarizes that such loss of nitrogen can not be less than 0.3 gram per day on the average. With the greater average activity of our subjects, as compared with the activity of the ordinary individual, 0.4 gram per day would be a closer estimate of the loss of nitrogen in this way. Hence, it can be seen that, in each case, 0.4 gram per day should be added to the nitrogen outgo to obtain the true nitrogen balance. Since the whole research extended over 103 days, we have an excretion of probably not less than 40 grams of cutaneous nitrogen which is not considered in either the urinary or the fecal loss. This will, in large part, at least, compensate for the excess nitrogen taken on the uncontrolled days. Accordingly, since there is uncertainty both as to the actual amount of nitrogen taken on the uncontrolled days and the cutaneous excretion, it seems best for purposes of discussion to omit both factors and to make the assumption, which may fairly be challenged, that these two more or less offset each other. With this preliminary announcement, therefore, we may consider the nitrogen balance as computed from the determination of the nitrogen in food, feces, and urine.

A suggestion of great nitrogen losses appears in a previous section in a general comparison of the food intake and the nitrogen in urine, (see page 300) but no consideration was given to the nitrogen in feces. In the comparison given in this discussion, a more exact balance is made by allowing for the fecal nitrogen. These nitrogen balances are computed for each member of Squad A and combined in tabular form with the comparisons of the energy intake and output. The energy balances will be discussed later but are tabulated here for convenience. The great significance of the nitrogen balance makes it desirable, furthermore, to present all of the data in detail, and this is done in tables 46 to 58 for Squad A and in tables 59 to 70 for Squad B.

[1] Taylor, Digestion and metabolism, Philadelphia, 1912, p. 485.

## NITROGEN BALANCE AND ENERGY AVAILABLE TO BODY, SQUAD A.

TABLE 46.—*Nitrogen balance and energy available to body*—GEORGE A. BROWN.

| Date. | Nitrogen per 24 hours in— Food. | Feces.[1] | Urine. | Nitrogen balance. | Energy per 24 hours of— Food. | Feces.[1] | Urine. (N×8.0). | Net energy. |
|---|---|---|---|---|---|---|---|---|
| 1917. | gm. | gm. | gm. | gm. | cals. | cals. | cals. | cals. |
| Normal diet: | | | | | | | | |
| Sept. 27–28 | ...... | ...... | 12.01 | ...... | ...... | ...... | ...... | ...... |
| Sept. 28–29 | ...... | ...... | 9.98 | ...... | ...... | ...... | ...... | ...... |
| Sept. 29–30 | ...... | ...... | 9.90 | ...... | ...... | ...... | ...... | ...... |
| Sept. 30–Oct. 1 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Oct. 1– 2 | 14.63 | 1.95 | 11.72 | + .96 | 3,300 | 166 | 94 | 3,040 |
| Oct. 2– 3 | 14.93 | 1.95 | 12.38 | + .60 | 2,974 | 166 | 99 | 2,709 |
| Oct. 3– 4 | 15.54 | 1.95 | 11.42 | +2.17 | 3,656 | 166 | 91 | 3,399 |
| Av. Oct. 1–4 | 15.03 | ...... | 11.84 | ...... | ...... | ...... | ...... | 3,049 |
| Reduced diet: | | | | | | | | |
| Oct. 4– 5 | 10.46 | (1.75) | 10.82 | −2.11 | 2,288 | (169) | 87 | 2,032 |
| Oct. 5– 6 | 11.85 | (1.75) | 11.77 | −1.67 | 2,103 | (169) | 94 | 1,840 |
| Oct. 6– 7 | 10.87 | (1.75) | 11.25 | −2.13 | 2,529 | (169) | 90 | 2,270 |
| Oct. 7– 8 | 9.24 | (1.75) | 11.35 | −3.86 | 2,052 | (169) | 91 | 1,792 |
| Oct. 8– 9 | 13.98 | 1.54 | 10.15 | +2.29 | 2,391 | 171 | 81 | 2,139 |
| Oct. 9–10 | 12.36 | 1.54 | 13.75 | −2.93 | 2,212 | 171 | 110 | 1,931 |
| Oct. 10–11 | 12.35 | 1.54 | 11.59 | − .78 | 2,350 | 171 | 93 | 2,086 |
| Oct. 11–12 | 10.96 | 1.54 | 9.89 | − .47 | 2,335 | 171 | 79 | 2,085 |
| Oct. 12–13 | 11.63 | (1.13) | 10.37 | + .13 | 2,556 | (148) | 83 | 2,325 |
| Oct. 13–14 | 9.59 | (1.13) | 10.21 | −1.75 | 2,281 | (148) | 82 | 2,051 |
| Oct. 14–15 | [2]15.13 | ...... | ...... | ...... | [3]3,758 | (148) | (86) | 3,524 |
| Av. Oct. 4–15 | 11.67 | ...... | 11.12 | ...... | ...... | ...... | ...... | 2,189 |
| Oct. 15–16 | 10.50 | (1.13) | 11.13 | −1.76 | 1,866 | (148) | 89 | 1,629 |
| Oct. 16–17 | 12.29 | (1.13) | 11.77 | − .61 | 2,026 | (148) | 94 | 1,784 |
| Oct. 17–18 | 9.83 | .72 | 11.22 | −2.11 | 1,752 | 124 | 90 | 1,538 |
| Oct. 18–19 | 14.30 | .72 | 12.43 | +1.15 | 2,497 | 124 | 99 | 2,274 |
| Oct. 19–20 | 9.99 | .72 | 10.02 | − .75 | 1,721 | 124 | 80 | 1,517 |
| Oct. 20–21 | 10.25 | .72 | 11.50 | −1.97 | 1,947 | 124 | 92 | 1,731 |
| Oct. 21–22 | 9.71 | ( .73) | 11.16 | −2.18 | 2,369 | (115) | 89 | 2,165 |
| Oct. 22–23 | 8.72 | ( .73) | 9.44 | −1.45 | 1,632 | (115) | 76 | 1,441 |
| Oct. 23–24 | 10.84 | ( .73) | 10.45 | − .34 | 2,138 | (115) | 84 | 1,939 |
| Oct. 24–25 | 12.48 | ( .73) | 10.75 | +1.00 | 2,306 | (115) | 86 | 2,105 |
| Oct. 25–26 | 7.83 | ( .73) | 8.80 | −1.70 | 1,400 | (115) | 70 | 1,215 |
| Oct. 26–27 | 10.78 | ( .73) | 9.24 | + .81 | 2,046 | (115) | 74 | 1,857 |
| Oct. 27–28 | 9.03 | ( .73) | 9.34 | −1.04 | 1,869 | (115) | 75 | 1,679 |
| Oct. 28–29 | [2]15.13 | ...... | ...... | ...... | [3]3,758 | (115) | (71) | 3,572 |
| Oct. 29–30 | 11.26 | ( .73) | 8.36 | +2.17 | 1,893 | (115) | 67 | 1,711 |
| Av. Oct. 15–30 | 10.86 | ...... | 10.40 | ...... | ...... | ...... | ...... | 1,877 |
| Oct. 30–31 | 11.59 | ( .73) | ...... | ...... | 1,614 | (115) | (75) | 1,424 |
| Oct. 31–Nov. 1 | 8.65 | .73 | 10.21 | −2.29 | 1,585 | 105 | 82 | 1,398 |
| Nov. 1– 2 | 5.64 | .73 | 9.36 | −4.45 | 917 | 105 | 75 | 737 |
| Nov. 2– 3 | 10.16 | .73 | 11.27 | −1.84 | 1,841 | 105 | 90 | 1,646 |
| Nov. 3– 4 | 8.01 | .73 | 11.68 | −4.40 | 1,604 | 105 | 93 | 1,406 |
| Nov. 4– 5 | 8.61 | ( .99) | 11.37 | −3.75 | 1,758 | (133) | 91 | 1,534 |

[1] In this table and in tables 47 to 70 the values in parentheses for nitrogen and energy in feces, are interpolated between determinations made in digestion periods. See table 37, p. 293.
[2] Assumed.
[3] Computed; see table 33, p. 269.

TABLE 46.—*Nitrogen balance and energy available to body*—GEORGE A. BROWN—continued.

[1] In this table and in tables 47 to 70 the values in parentheses for nitrogen and energy in feces are interpolated between determinations made in digestion periods. See table 37, p. 293.
[2] Computed; see table 33, p. 269.
[3] Dec. 20, 1917, to Jan. 7, 1918 (inclusive), Christmas recess.

TABLE 46.—*Nitrogen balance and energy available to body*—GEORGE A. BROWN—continued.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces.[1] | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1918. | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Reduced diet—*cont.* | | | | | | | | |
| Jan. 8– 9 | 8.85 | (1.21) | 7.03 | + .61 | 1,475 | (153) | 56 | 1,266 |
| Jan. 9–10 | 8.15 | (1.21) | 9.05 | −2.11 | 1,368 | (153) | 72 | 1,143 |
| Jan. 10–11 | 4.14 | (1.21) | 9.87 | −6.94 | 931 | (153) | 79 | 699 |
| Jan. 11–12 | 7.21 | (1.21) | 10.11 | −4.11 | 1,117 | (153) | 81 | 883 |
| Jan. 12–13 | 8.46 | (1.21) | 10.39 | −3.14 | 1,772 | (153) | 83 | 1,536 |
| Jan. 13–14 | [1]20.09 | (1.21) | 12.67 | +6.21 | [1]4,385 | (153) | 101 | 4,131 |
| Jan. 14–15 | 2.72 | 1.18 | 6.35 | −4.81 | 584 | 145 | 51 | 388 |
| Jan. 15–16 | 4.81 | 1.18 | 6.22 | −2.59 | 902 | 145 | 50 | 707 |
| Av. Jan. 8–16 | 8.05 | ...... | 8.96 | ...... | ...... | ...... | ...... | 1,344 |
| Jan. 16–17 | 10.47 | 1.18 | 9.79 | − .50 | 1,941 | 145 | 78 | 1,718 |
| Jan. 17–18 | 11.66 | 1.18 | 11.10 | − .62 | 1,853 | 145 | 89 | 1,619 |
| Jan. 18–19 | 11.32 | 1.18 | 10.71 | − .57 | 1,947 | 145 | 86 | 1,716 |
| Jan. 19–20 | 10.95 | 1.18 | 9.24 | + .53 | 2,256 | 145 | 74 | 2,037 |
| Jan. 20–21 | 8.45 | 1.18 | 10.19 | −2.92 | 1,781 | 145 | 82 | 1,554 |
| Jan. 21–22 | 8.28 | 1.18 | 10.07 | −2.97 | 1,435 | 145 | 81 | 1,209 |
| Jan. 22–23 | 10.12 | 1.18 | 10.42 | −1.48 | 1,663 | 145 | 83 | 1,435 |
| Jan. 23–24 | 7.85 | 1.18 | 10.88 | −4.21 | 1,647 | 145 | 87 | 1,415 |
| Jan. 24–25 | 10.66 | 1.18 | 11.53 | −2.05 | 2,046 | 145 | 92 | 1,809 |
| Jan. 25–26 | 8.91 | 1.18 | 9.62 | −1.89 | 1,964 | 145 | 77 | 1,742 |
| Jan. 26–27 | 10.51 | 1.18 | 10.34 | −1.01 | 2,155 | 145 | 83 | 1,927 |
| Jan. 27–28 | 9.11 | 1.18 | 11.29 | −3.36 | 1,741 | 145 | 90 | 1,506 |
| Jan. 28–29 | 12.44 | 1.18 | 9.55 | +1.71 | 2,278 | 145 | 76 | 2,057 |
| Jan. 29–30 | 17.53 | 1.18 | 12.25 | +4.10 | 3,100 | 145 | 98 | 2,857 |
| Jan. 30–31 | 12.01 | (1.18) | 9.95 | + .88 | 2,731 | (145) | 80 | 2,506 |
| Jan. 31–Feb. 1 | 19.83 | (1.18) | 15.23 | +3.42 | 3,337 | (145) | 122 | 3,070 |
| Feb. 1– 2 | 16.30 | (1.18) | 13.29 | +1.83 | 2,959 | (145) | 106 | 2,708 |
| Feb. 2– 3 | 10.46 | (1.18) | 12.68 | −3.40 | 2,116 | (145) | 101 | 1,870 |
| Av. Jan. 16–Feb. 3. | 11.49 | ...... | 11.01 | ...... | ...... | ...... | ...... | 1,931 |

[1] Computed; see table 33, p. 269.

TABLE 47.—*Nitrogen balance and energy available to body*—KENNETH B. CANFIELD.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1917. | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Normal diet: | | | | | | | | |
| Sept. 27–28 | ...... | ...... | 11.47 | ...... | ...... | ...... | ...... | ...... |
| Sept. 28–29 | ...... | ...... | 13.36 | ...... | ...... | ...... | ...... | ...... |
| Sept. 29–30 | ...... | ...... | 11.50 | ...... | ...... | ...... | ...... | ...... |
| Sept. 30–Oct. 1 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Oct. 1–2 | 15.59 | 1.36 | 13.60 | + .63 | 3,471 | 134 | 109 | 3,228 |
| Oct. 2–3 | 14.93 | 1.36 | 13.27 | + .30 | 2,974 | 134 | 106 | 2,734 |
| Oct. 3–4 | 15.54 | 1.36 | 14.41 | – .23 | 3,656 | 134 | 115 | 3,407 |
| Av. Oct. 1–4 | 15.35 | ...... | 13.76 | ...... | ...... | ...... | ...... | 3,123 |
| Reduced diet: | | | | | | | | |
| Oct. 4–5 | 10.46 | (1.36) | 13.46 | –4.36 | 2,304 | (141) | 108 | 2,055 |
| Oct. 5–6 | 11.85 | (1.36) | 13.00 | –2.51 | 2,119 | (141) | 104 | 1,874 |
| Oct. 6–7 | 10.87 | (1.36) | 13.34 | –3.83 | 2,545 | (141) | 107 | 2,297 |
| Oct. 7–8 | 9.26 | (1.36) | 13.65 | –5.75 | 2,089 | (141) | 109 | 1,839 |
| Oct. 8–9 | 13.82 | 1.35 | 15.24 | –2.77 | 2,379 | 147 | 122 | 2,110 |
| Oct. 9–10 | 12.21 | 1.35 | 13.50 | –2.64 | 2,199 | 147 | 108 | 1,944 |
| Oct. 10–11 | 12.19 | 1.35 | 14.41 | –3.57 | 2,337 | 147 | 115 | 2,075 |
| Oct. 11–12 | 11.03 | 1.35 | 12.09 | –2.41 | 2,363 | 147 | 97 | 2,119 |
| Oct. 12–13 | 12.39 | (1.11) | 13.14 | –1.86 | 2,713 | (130) | 105 | 2,478 |
| Oct. 13–14 | 9.47 | (1.11) | 12.10 | –3.74 | 2,276 | (130) | 97 | 2,049 |
| Oct. 14–15 | [1]13.45 | ...... | ...... | ...... | [1]3,088 | (130) | (96) | 2,862 |
| Av. Oct. 4–15 | 11.55 | ...... | 13.39 | ...... | ...... | ...... | ...... | 2,155 |
| Oct. 15–16 | 11.13 | (1.11) | 11.89 | –1.87 | 1,990 | (130) | 95 | 1,765 |
| Oct. 16–17 | 12.67 | (1.11) | 12.43 | – .87 | 2,104 | (130) | 99 | 1,875 |
| Oct. 17–18 | 10.14 | .86 | 12.39 | –3.11 | 1,826 | 113 | 99 | 1,614 |
| Oct. 18–19 | 14.30 | .86 | 13.99 | – .55 | 2,505 | 113 | 112 | 2,280 |
| Oct. 19–20 | 9.53 | .86 | 11.45 | –2.78 | 1,650 | 113 | 92 | 1,445 |
| Oct. 20–21 | 9.94 | .86 | 12.26 | –3.18 | 1,897 | 113 | 98 | 1,686 |
| Oct. 21–22 | 9.55 | ( .97) | 10.56 | –1.98 | 2,340 | (126) | 84 | 2,130 |
| Oct. 22–23 | 8.72 | ( .97) | 9.60 | –1.85 | 1,640 | (126) | 77 | 1,437 |
| Oct. 23–24 | 10.85 | ( .97) | 10.10 | – .22 | 2,317 | (126) | 81 | 2,110 |
| Oct. 24–25 | 12.02 | ( .97) | 10.94 | + .11 | 2,219 | (126) | 88 | 2,005 |
| Oct. 25–26 | 7.68 | ( .97) | 10.77 | –4.06 | 1,355 | (126) | 86 | 1,143 |
| Oct. 26–27 | 10.47 | ( .97) | 8.92 | + .58 | 1,976 | (126) | 71 | 1,779 |
| Oct. 27–28 | 8.25 | ( .97) | 10.35 | –3.07 | 1,716 | (126) | 83 | 1,507 |
| Oct. 28–29 | [2]13.45 | ...... | ...... | ...... | [2]3,088 | (126) | (75) | 2,887 |
| Av. Oct. 15–29 | 10.62 | ...... | 11.20 | ...... | ...... | ...... | ...... | 1,833 |
| Oct. 29–30 | 10.95 | ( .97) | 8.24 | +1.74 | 1,835 | (126) | 66 | 1,643 |
| Oct. 30–31 | 12.14 | ( .97) | 10.63 | + .54 | 1,676 | (126) | 85 | 1,465 |
| Oct. 31–Nov. 1 | 8.97 | 1.07 | 12.22 | –4.32 | 1,750 | 138 | 98 | 1,514 |
| Nov. 1–2 | 8.89 | 1.07 | 12.42 | –4.60 | 1,454 | 138 | 99 | 1,217 |
| Nov. 2–3 | 10.08 | 1.07 | 11.07 | –2.06 | 1,945 | 138 | 89 | 1,718 |
| Nov. 3–4 | 8.33 | 1.07 | 10.72 | –3.46 | 1,746 | 138 | 86 | 1,522 |
| Nov. 4–5 | 8.30 | (1.16) | 11.32 | –4.18 | 1,779 | (153) | 91 | 1,535 |
| Av. Oct. 29–Nov. 5 | 9.67 | ...... | 10.95 | ...... | ...... | ...... | ...... | 1,516 |

[1] Assumed [2] Computed; see table 33, p. 269

TABLE 47.—*Nitrogen balance and energy available to body*—KENNETH B. CANFIELD—continued.

[1] Computed; see table 33, p. 269.
[2] Nov. 30–Dec. 2 (inclusive), Thanksgiving recess.
[3] Assumed.
[4] Dec. 20, 1917–Jan. 6, 1918 (inclusive), Christmas recess.

TABLE 47.—*Nitrogen balance and energy available to body*—KENNETH B. CANFIELD—continued.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1918. | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Reduced diet—*cont.* | | | | | | | | |
| Jan. 7- 8 | 7.63 | (1.76) | 11.75 | −5.88 | 1,282 | (215) | 94 | 973 |
| Jan. 8- 9 | 9.49 | (1.76) | 11.66 | −3.93 | 1,590 | (215) | 93 | 1,282 |
| Av. Jan. 7-9 | 8.56 | ...... | 11.71 | ...... | ...... | ...... | ...... | 1,128 |
| Jan. 9-10 | 13.37 | (1.76) | 14.37 | −2.76 | 2,414 | (215) | 115 | 2,084 |
| Jan. 10-11 | 10.66 | (1.76) | 14.07 | −5.17 | 2,087 | (215) | 113 | 1,759 |
| Jan. 11-12 | 13.10 | (1.76) | 7.70 | +3.64 | 2,078 | (215) | 62 | 1,801 |
| Jan. 12-13 | 11.75 | (1.76) | 12.88 | −2.89 | 2,364 | (215) | 103 | 2,046 |
| Jan. 13-14 | [1]17.54 | (1.76) | 13.82 | +1.96 | [1]3,964 | (215) | 111 | 3,638 |
| Jan. 14-15 | 12.73 | 1.76 | 10.57 | + .40 | 2,325 | 215 | 85 | 2,025 |
| Jan. 15-16 | 10.45 | 1.76 | 11.68 | −2.99 | 1,841 | 215 | 93 | 1,533 |
| Jan. 16-17 | 15.05 | 1.76 | 13.06 | + .23 | 2,828 | 215 | 104 | 2,509 |
| Jan. 17-18 | 11.83 | 1.76 | 11.35 | −1.28 | 1,929 | 215 | 91 | 1,623 |
| Jan. 18-19 | 17.25 | 1.76 | 13.94 | +1.55 | 3,022 | 215 | 112 | 2,695 |
| Jan. 19-20 | 16.51 | 1.76 | 13.48 | +1.27 | 3,353 | 215 | 108 | 3,030 |
| Jan. 20-21 | 9.44 | 1.76 | 12.37 | −4.69 | 2,018 | 215 | 99 | 1,704 |
| Jan. 21-22 | 15.57 | 1.76 | 11.79 | +2.02 | 2,682 | 215 | 94 | 2,373 |
| Jan. 22-23 | 19.45 | 1.76 | 14.97 | +2.72 | 3,298 | 215 | 120 | 2,963 |
| Jan. 23-24 | 18.35 | 1.76 | 14.39 | +2.20 | 3,919 | 215 | 115 | 3,589 |
| Jan. 24-25 | 10.51 | 1.76 | 13.25 | −4.50 | 2,056 | 215 | 106 | 1,735 |
| Jan. 25-26 | 13.67 | 1.76 | 12.53 | − .62 | 3,198 | 215 | 100 | 2,883 |
| Jan. 26-27 | 11.49 | 1.76 | 12.32 | −2.59 | 2,389 | 215 | 99 | 2,075 |
| Jan. 27-28 | 8.75 | 1.76 | 14.13 | −7.14 | 1,670 | 215 | 113 | 1,342 |
| Jan. 28-29 | 21.55 | 1.76 | 14.18 | +5.61 | 4,159 | 215 | 113 | 3,831 |
| Jan. 29-30 | 17.27 | 1.76 | 13.17 | +2.34 | 3,057 | 215 | 105 | 2,737 |
| Jan. 30-31 | 11.47 | (1.76) | 12.42 | −2.71 | 2,636 | (215) | 99 | 2,322 |
| Jan. 31-Feb. 1 | 19.30 | (1.76) | 14.02 | +3.52 | 3,234 | (215) | 112 | 2,907 |
| Feb. 1- 2 | 16.30 | (1.76) | 13.84 | + .70 | 2,959 | (215) | 111 | 2,633 |
| Feb. 2- 3 | 10.46 | (1.76) | 11.52 | −2.82 | 2,132 | (215) | 92 | 1,825 |
| Av. Jan. 9-Feb. 3 | 14.15 | ...... | 12.87 | ...... | ...... | ...... | ...... | 2,386 |

[1] Computed; see table 33, p. 269.

TABLE 48.—*Nitrogen balance and energy available to body*—LESTER F. FRETTER.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1917. | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Normal diet: | | | | | | | | |
| Sept. 27-28 | ...... | ...... | 11.83 | ...... | ...... | ...... | ...... | ...... |
| Sept. 28-29 | ...... | ...... | 12.40 | ...... | ...... | ...... | ...... | ...... |
| Sept. 29-30 | ...... | ...... | 10.40 | ...... | ...... | ...... | ...... | ...... |
| Sept. 30-Oct. 1 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Oct. 1- 2 | 15.53 | 1.86 | 12.02 | +1.65 | 3,408 | 154 | 96 | 3,158 |
| Oct. 2- 3 | 14.93 | 1.86 | 14.29 | −1.22 | 2,974 | 154 | 114 | 2,706 |
| Oct. 3- 4 | 15.54 | 1.86 | 12.40 | +1.28 | 3,656 | 154 | 99 | 3,403 |
| Av. Oct. 1-4 | 15.33 | ...... | 12.90 | ...... | ...... | ...... | ...... | 3,089 |

TABLE 48.—*Nitrogen balance and energy available to body*—LESTER F. FRETTER—continued.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine. (N×8.0). | |
| 1917—*continued.* | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Reduced diet—*cont.* | | | | | | | | |
| Oct. 4– 5 | 10.46 | (1.71) | 11.53 | −2.78 | 2,296 | (150) | 92 | 2,054 |
| Oct. 5– 6 | 11.85 | (1.71) | 11.86 | −1.72 | 2,111 | (150) | 95 | 1,866 |
| Oct. 6– 7 | 10.87 | (1.71) | 11.66 | −2.50 | 2,537 | (150) | 93 | 2,294 |
| Oct. 7– 8 | 9.49 | (1.71) | 12.53 | −4.75 | 2,074 | (150) | 100 | 1,824 |
| Oct. 8– 9 | 13.82 | 1.56 | 12.16 | + .10 | 2,371 | 145 | 97 | 2,129 |
| Oct. 9–10 | 12.25 | 1.56 | 10.34 | + .35 | 2,183 | 145 | 83 | 1,955 |
| Oct. 10–11 | 11.52 | 1.56 | 12.16 | −2.20 | 2,205 | 145 | 97 | 1,963 |
| Oct. 11–12 | 10.80 | 1.56 | 10.02 | − .78 | 2,314 | 145 | 80 | 2,089 |
| Oct. 12–13 | 10.48 | (1.23) | 12.22 | −2.97 | 2,212 | (114) | 98 | 2,000 |
| Oct. 13–14 | 8.60 | (1.23) | 9.99 | −2.62 | 1,984 | (114) | 80 | 1,790 |
| Oct. 14–15 | ...... | ...... | ...... | ...... | ...... | (114) | (77) | [1]4,000 |
| Av. Oct. 4–15 | 11.01 | ...... | 11.45 | ...... | ...... | ...... | ...... | 2,179 |
| Oct. 15–16 | 10.73 | (1.23) | 9.30 | + .20 | 1,915 | (114) | 74 | 1,727 |
| Oct. 16–17 | 11.98 | (1.23) | 11.95 | −1.20 | 1,968 | (114) | 96 | 1,758 |
| Oct. 17–18 | 9.38 | .90 | 11.71 | −3.23 | 1,677 | 82 | 94 | 1,501 |
| Oct. 18–19 | 12.90 | .90 | 12.55 | − .55 | 2,228 | 82 | 100 | 2,046 |
| Oct. 19–20 | 10.06 | .90 | 10.89 | −1.73 | 1,835 | 82 | 87 | 1,666 |
| Oct. 20–21 | 9.47 | .90 | 10.31 | −1.74 | 1,802 | 82 | 82 | 1,638 |
| Oct. 21–22 | 10.15 | ( .90) | 10.08 | − .83 | 2,653 | ( 82) | 81 | 2,490 |
| Oct. 22–23 | 8.25 | ( .90) | 8.81 | −1.46 | 1,553 | ( 82) | 70 | 1,401 |
| Oct. 23–24 | 10.98 | ( .90) | 10.77 | − .69 | 2,274 | ( 82) | 86 | 2,106 |
| Oct. 24–25 | 11.36 | ( .90) | 11.65 | −1.19 | 2,119 | ( 82) | 93 | 1,944 |
| Av. Oct. 15–25 | 10.53 | ...... | 10.80 | ...... | ...... | ...... | ...... | 1,828 |

[1] Estimate from diet of normal subjects.

TABLE 49.—*Nitrogen balance and energy available to body*—EVERETT R. KONTNER.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1917. | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Reduced diet:[1] | | | | | | | | |
| Oct. 30–31 | 10.84 | ( .87) | 15.48 | −5.51 | 1,404 | (125) | 124 | 1,155 |
| Oct. 31–Nov. 1 | 7.95 | .87 | 10.81 | −3.73 | 1,383 | 125 | 86 | 1,172 |
| Nov. 1– 2 | 8.64 | .87 | 15.80 | −8.03 | 1,336 | 125 | 126 | 1,085 |
| Nov. 2– 3 | 9.44 | .87 | 13.35 | −4.78 | 1,716 | 125 | 107 | 1,484 |
| Nov. 3– 4 | 10.12 | .87 | 11.62 | −2.37 | 1,861 | 125 | 93 | 1,643 |
| Nov. 4– 5 | 8.61 | ( .97) | 11.75 | −4.11 | 1,766 | (138) | 94 | 1,534 |
| Nov. 5– 6 | 9.59 | ( .97) | 12.76 | −4.14 | 1,476 | (138) | 102 | 1,236 |
| Nov. 6– 7 | 8.15 | ( .97) | 11.72 | −4.54 | 1,563 | (138) | 94 | 1,331 |
| Nov. 7– 8 | 8.88 | ( .97) | 11.34 | −3.43 | 1,819 | (138) | 91 | 1,590 |
| Nov. 8– 9 | 6.26 | ( .97) | 10.39 | −5.10 | 1,298 | (138) | 83 | 1,077 |
| Nov. 9–10 | 7.05 | ( .97) | 8.83 | −2.75 | 1,233 | (138) | 71 | 1,024 |

[1] Estimates of the intake in the diets for Oct. 28–29 and Oct. 29–30 were as follows: Oct. 28–29, nitrogen, 12.34 gms.; energy, 2,377 cals.; Oct. 29–30, nitrogen, 18.26 gms.; energy, 3,641 cals.

TABLE 49.—*Nitrogen balance and energy available to body*—EVERETT R. KONTNER—continued.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1917—*continued.* | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Reduced diet—*cont.* | | | | | | | | |
| Nov. 10–11 | 8.70 | ( .97) | 11.11 | −3.38 | 1,548 | (138) | 89 | 1,321 |
| Nov. 11–12 | [1]18.36 | ...... | ...... | ...... | [1]4,569 | (138) | (91) | 4,340 |
| Nov. 12–13 | 6.65 | 1.06 | 11.61 | −6.02 | 1,400 | 150 | 93 | 1,157 |
| Nov. 13–14 | 10.75 | 1.06 | 11.01 | −1.32 | 1,704 | 150 | 88 | 1,466 |
| Nov. 14–15 | 9.47 | 1.06 | 11.68 | −3.27 | 1,550 | 150 | 93 | 1,307 |
| Nov. 15–16 | 8.01 | 1.06 | 11.74 | −4.79 | 1,498 | 150 | 94 | 1,254 |
| Nov. 16–17 | 8.52 | 1.06 | 13.03 | −5.57 | 1,058 | 150 | 104 | 804 |
| Nov. 17–18 | 8.50 | 1.06 | 12.08 | −4.64 | 1,714 | 150 | 97 | 1,467 |
| Nov. 18–19 | 8.19 | (1.07) | 12.06 | −4.94 | 1,643 | (150) | 96 | 1,397 |
| Nov. 19–20 | 10.91 | (1.07) | 10.04 | − .20 | 2,133 | (150) | 80 | 1,903 |
| Nov. 20–21 | 10.40 | (1.07) | 11.22 | −1.89 | 1,738 | (150) | 90 | 1,498 |
| Nov. 21–22 | 6.95 | (1.07) | 11.82 | −5.94 | 1,596 | (150) | 95 | 1,351 |
| Nov. 22–23 | 8.39 | (1.07) | 9.72 | −2.40 | 1,842 | (150) | 78 | 1,614 |
| Nov. 23–24 | 8.16 | (1.07) | 9.64 | −2.55 | 1,755 | (150) | 77 | 1,528 |
| Nov. 24–25 | 9.16 | (1.07) | 11.49 | −3.40 | 1,741 | (150) | 92 | 1,499 |
| Nov. 25–26 | [1]24.01 | ...... | ...... | ...... | [1]5,256 | (150) | (94) | 5,012 |
| Nov. 26–27 | 6.36 | (1.07) | 11.86 | −6.57 | 1,165 | (150) | 95 | 920 |
| Nov. 27–28 | 9.40 | (1.07) | 12.06 | −3.73 | 1,675 | (150) | 96 | 1,429 |
| Nov. 28–29[2] | 7.42 | (1.07) | ...... | ...... | 1,729 | (150) | (96) | 1,483 |
| Av. Oct. 30–Nov. 29. | 9.46 | ...... | 11.70 | ...... | ...... | ...... | ...... | 1,569 |
| Dec. 3– 4 | 7.76 | (1.07) | 11.63 | −4.94 | 1,471 | (150) | 93 | 1,228 |
| Dec. 4– 5 | 11.12 | (1.07) | 15.51 | −5.46 | 1,876 | (150) | 124 | 1,602 |
| Dec. 5– 6 | 8.81 | (1.07) | 15.68 | −7.94 | 1,750 | (150) | 125 | 1,475 |
| Dec. 6– 7 | 8.54 | (1.07) | 17.35 | −9.88 | 1,781 | (150) | 139 | 1,492 |
| Dec. 7– 8 | 6.57 | (1.07) | 13.18 | −7.68 | 1,509 | (150) | 105 | 1,254 |
| Dec. 8– 9 | 7.86 | (1.07) | 14.15 | −7.36 | 1,620 | (150) | 113 | 1,357 |
| Dec. 9–10 | [3]24.01 | ...... | ...... | ...... | [3]5,256 | (150) | (98) | 5,008 |
| Dec. 10–11 | 7.76 | 1.07 | 10.31 | −3.62 | 1,954 | 150 | 82 | 1,722 |
| Dec. 11–12 | 10.12 | 1.07 | 11.03 | −1.98 | 2,019 | 150 | 88 | 1,781 |
| Dec. 12–13 | 11.39 | 1.07 | 14.03 | −3.71 | 2,229 | 150 | 112 | 1,967 |
| Dec. 13–14 | 7.86 | 1.07 | 14.67 | −7.88 | 1,491 | 150 | 117 | 1,224 |
| Dec. 14–15 | 8.17 | 1.07 | 9.88 | −2.78 | 2,068 | 150 | 79 | 1,839 |
| Dec. 15–16 | 10.51 | (1.07) | 11.54 | −2.10 | 2,668 | (150) | 92 | 2,426 |
| Dec. 16–17 | 9.17 | (1.07) | ...... | ...... | 2,041 | (150) | (97) | 1,794 |
| Dec. 17–18 | 11.55 | (1.07) | 12.75 | −2.27 | 2,089 | (150) | 102 | 1,837 |
| Dec. 18–19 | 10.50 | (1.07) | 11.99 | −2.56 | 2,082 | (150) | 96 | 1,836 |
| Dec. 19–20[4] | 9.59 | (1.07) | 12.81 | −4.29 | 2,179 | (150) | 102 | 1,927 |
| Av. Dec. 3–20 | 10.08 | ...... | 13.10 | ...... | ...... | ...... | ...... | 1,869 |
| 1918. | | | | | | | | |
| Jan. 12–13 | 8.14 | ( .88) | 12.08 | −4.82 | 1,746 | (129) | 97 | 1,520 |
| Jan. 13–14 | [1]28.47 | ( .88) | 11.75 | +15.84 | [1]5,264 | (129) | 94 | 5,041 |
| Jan. 14–15 | 3.90 | ( .88) | 8.56 | −5.54 | 922 | (129) | 68 | 725 |
| Jan. 15–16 | 6.82 | .88 | 8.48 | −2.54 | 1,245 | 129 | 68 | 1,048 |
| Jan. 16–17 | 6.19 | .88 | 7.88 | −2.57 | 1,177 | 129 | 63 | 985 |

[1] Computed; see table 33, p. 269.
[2] Nov. 29–Dec. 2 (inclusive), Thanksgiving recess.
[3] Assumed.
[4] Dec. 20, 1917–Jan. 11, 1918 (inclusive), Christmas recess.

TABLE 49.—*Nitrogen balance and energy available to body*—EVERETT R. KONTNER—continued.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine. (N×8.0). | |
| 1918—*continued.* | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Reduced diet—*cont.* | | | | | | | | |
| Jan. 17–18 | 5.95 | .88 | 7.84 | −2.77 | 935 | 129 | 63 | 743 |
| Jan. 18–19 | 6.30 | .88 | 9.24 | −3.82 | 1,084 | 129 | 74 | 881 |
| Jan. 19–20 | 6.52 | .88 | 10.46 | −4.82 | 1,369 | 129 | 84 | 1,156 |
| Jan. 20–21 | 8.11 | .88 | 10.11 | −2.88 | 1,687 | 129 | 81 | 1,477 |
| Jan. 21–22 | 6.82 | .88 | 8.75 | −2.81 | 1,374 | 129 | 70 | 1,175 |
| Jan. 22–23 | 8.29 | .88 | 9.52 | −2.11 | 1,159 | 129 | 76 | 954 |
| Jan. 23–24 | 7.02 | .88 | 11.47 | −5.33 | 1,429 | 129 | 92 | 1,208 |
| Jan. 24–25 | 8.43 | .88 | 10.71 | −3.16 | 1,506 | 129 | 86 | 1,291 |
| Jan. 25–26 | 8.91 | .88 | 10.94 | −2.91 | 2,020 | 129 | 88 | 1,803 |
| Jan. 26–27 | 8.71 | .88 | 8.03 | − .20 | 1,932 | 129 | 64 | 1,739 |
| Jan. 27–28 | 8.75 | .88 | 11.12 | −3.25 | 1,694 | 129 | 89 | 1,476 |
| Jan. 28–29 | 8.81 | .88 | 9.43 | −1.50 | 1,800 | 129 | 75 | 1,596 |
| Jan. 29–30 | 11.25 | .88 | 11.81 | −1.44 | 2,126 | 129 | 94 | 1,903 |
| Jan. 30–31 | 9.41 | ( .88) | 8.26 | + .27 | 2,063 | (129) | 66 | 1,868 |
| Jan. 31–Feb. 1 | 12.29 | ( .88) | 10.93 | + .48 | 2,092 | (129) | 87 | 1,876 |
| Feb. 1– 2 | 16.03 | ( .88) | 13.10 | +2.05 | 2,926 | (129) | 105 | 2,692 |
| Feb. 2– 3 | 8.52 | ( .88) | 10.57 | −2.93 | 1,830 | (129) | 85 | 1,616 |
| Av. Jan. 12–Feb. 3. | 9.26 | ...... | 10.05 | ...... | ...... | ...... | ...... | 1,581 |

TABLE 50.—*Nitrogen balance and energy available to body*—GREYSON C. GARDNER.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1917. | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Normal diet: | | | | | | | | |
| Sept. 28–29 | ...... | ...... | 14.45 | ...... | ...... | ...... | ...... | ...... |
| Sept. 29–30 | ...... | ...... | 11.96 | ...... | ...... | ...... | ...... | ...... |
| Sept. 30–Oct. 1 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Oct. 1– 2 | 17.49 | 1.77 | 14.50 | +1.22 | 3,723 | 145 | 116 | 3,462 |
| Oct. 2– 3 | 14.61 | 1.77 | 13.56 | − .72 | 2,817 | 145 | 108 | 2,564 |
| Oct. 3– 4 | 15.54 | 1.77 | 14.03 | − .26 | 3,656 | 145 | 112 | 3,399 |
| Av. Oct. 1–4 | 15.88 | ...... | 14.03 | ...... | ...... | ...... | ...... | 3,142 |
| Reduced diet: | | | | | | | | |
| Oct. 4– 5 | 10.46 | (1.55) | 11.71 | −2.80 | 2,304 | (141) | 94 | 2,069 |
| Oct. 5– 6 | 11.85 | (1.55) | 10.71 | − .41 | 2,119 | (141) | 86 | 1,892 |
| Oct. 6– 7 | 10.87 | (1.55) | 11.43 | −2.11 | 2,545 | (141) | 91 | 2,313 |
| Oct. 7– 8 | 9.14 | (1.55) | 11.33 | −3.74 | 2,062 | (141) | 91 | 1,830 |
| Oct. 8– 9 | 13.67 | 1.33 | 12.22 | + .12 | 2,350 | 137 | 98 | 2,115 |
| Oct. 9–10 | 12.21 | 1.33 | 12.56 | −1.68 | 2,199 | 137 | 100 | 1,962 |
| Oct. 10–11 | 11.83 | 1.33 | 11.76 | −1.26 | 2,271 | 137 | 94 | 2,040 |
| Oct. 11–12 | 10.49 | 1.33 | 12.34 | −3.18 | 2,264 | 137 | 99 | 2,028 |
| Oct. 12–13 | 11.63 | (1.29) | 12.45 | −2.11 | 2,572 | (122) | 100 | 2,350 |
| Oct. 13–14 | 9.36 | (1.29) | 11.54 | −3.47 | 2,263 | (122) | 92 | 2,049 |
| Oct. 14–15 | [1]14.67 | ...... | ...... | ...... | [1]3,403 | (122) | (90) | 3,191 |
| Av. Oct. 4–15 | 11.47 | ...... | 11.81 | ...... | ...... | ...... | ...... | 2,167 |

[1] Assumed.

TABLE 50.—*Nitrogen balance and energy available to body*—GREYSON C. GARDNER—continued.

[1] Computed; see table 33, p. 269. [2] Nov. 29–Dec. 2 (inclusive), Thanksgiving recess.

TABLE 50.—*Nitrogen balance and energy available to body*—GREYSON C. GARDNER—continued.

[1] Computed; see table 33, p. 269. [2] Dec. 20, 1917–Jan. 6, 1918 (inclusive), Christmas recess.

TABLE 51.—*Nitrogen balance and energy available to body*—OTTO A. GULLICKSON.

[1] Assumed. [2] Computed; see table 33, p. 269.

TABLE 51.—*Nitrogen balance and energy available to body*—OTTO A. GULLICKSON—continued.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1917—*continued.* Reduced diet—*cont.* | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Nov. 12–13 | 8.37 | .91 | 8.60 | −1.14 | 1,800 | 127 | 69 | 1,604 |
| Nov. 13–14 | 11.66 | .91 | 9.52 | +1.23 | 1,925 | 127 | 76 | 1,722 |
| Nov. 14–15 | 10.83 | .91 | 11.39 | −1.47 | 1,692 | 127 | 91 | 1,474 |
| Nov. 15–16 | 7.85 | .91 | 11.04 | −4.10 | 1,485 | 127 | 88 | 1,270 |
| Nov. 16–17 | 9.78 | .91 | 10.90 | −2.03 | 1,444 | 127 | 87 | 1,230 |
| Nov. 17–18 | 8.67 | .91 | 10.87 | −3.11 | 1,779 | 127 | 87 | 1,565 |
| Nov. 18–19 | 8.95 | (1.23) | 9.35 | −1.63 | 1,820 | (177) | 75 | 1,568 |
| Nov. 19–20 | 11.86 | (1.23) | 10.51 | + .12 | 2,296 | (177) | 84 | 2,035 |
| Nov. 20–21 | 11.65 | (1.23) | 9.25 | +1.17 | 1,998 | (177) | 74 | 1,747 |
| Nov. 21–22 | 11.04 | (1.23) | 10.01 | − .20 | 2,375 | (177) | 80 | 2,118 |
| Nov. 22–23 | 9.45 | (1.23) | 8.99 | − .77 | 2,092 | (177) | 72 | 1,843 |
| Nov. 23–24 | 2.48 | (1.23) | 6.13 | −4.88 | 1,008 | (177) | 49 | 782 |
| Nov. 24–25 | 8.88 | (1.23) | 10.78 | −3.13 | 1,649 | (177) | 86 | 1,386 |
| Nov. 25–26 | [1]14.05 | ...... | ...... | ...... | [1]4,830 | (177) | (73) | 4,580 |
| Nov. 26–27 | 8.79 | (1.23) | 7.48 | + .08 | 1,604 | (177) | 60 | 1,367 |
| Nov. 27–28 | 7.95 | (1.23) | 9.56 | −2.84 | 1,489 | (177) | 76 | 1,236 |
| Nov. 28–29 | 7.73 | (1.23) | 7.16 | − .66 | 1,787 | (177) | 57 | 1,553 |
| Av. Nov. 12–29 | 9.41 | ...... | 9.47 | ...... | ...... | ...... | ...... | 1,711 |
| Nov. 29–30 | ...... | ...... | 5.59 | ...... | ...... | ...... | ...... | ...... |
| Nov. 30–Dec. 1 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Dec. 1– 2 | ...... | ...... | 3.90 | ...... | ...... | ...... | ...... | ...... |
| Dec. 2– 3 | ...... | ...... | 4.70 | ...... | ...... | ...... | ...... | ...... |
| Dec. 3– 4 | 3.68 | (1.23) | 5.51 | −3.06 | 755 | (177) | 44 | 534 |
| Dec. 4– 5 | 12.34 | (1.23) | 13.37 | −2.26 | 2,174 | (177) | 107 | 1,890 |
| Dec. 5– 6 | 10.02 | (1.23) | ...... | ...... | 2,003 | (177) | (89) | 1,737 |
| Dec. 6– 7 | 10.77 | (1.23) | 8.86 | + .68 | 2,276 | (177) | 71 | 2,028 |
| Dec. 7– 8 | 8.45 | (1.23) | 10.74 | −3.52 | 1,832 | (177) | 86 | 1,569 |
| Dec. 8– 9 | 8.80 | (1.23) | 8.85 | −1.28 | 1,790 | (177) | 71 | 1,542 |
| Dec. 9–10 | [1]14.95 | ...... | ...... | ...... | [1]5,355 | (177) | (72) | 5,106 |
| Dec. 10–11 | 9.95 | 1.54 | 9.11 | − .70 | 2,335 | 226 | 73 | 2,036 |
| Dec. 11–12 | 10.43 | 1.54 | 9.53 | − .64 | 2,037 | 226 | 76 | 1,735 |
| Dec. 12–13 | 12.02 | 1.54 | 11.28 | − .80 | 2,353 | 226 | 90 | 2,037 |
| Dec. 13–14 | 10.83 | 1.54 | 11.92 | −2.63 | 2,186 | 226 | 95 | 1,865 |
| Dec. 14–15 | 8.97 | 1.54 | 10.07 | −2.64 | 2,243 | 226 | 81 | 1,936 |
| Dec. 15–16 | 10.98 | (1.54) | 9.45 | − .01 | 2,756 | (226) | 76 | 2,454 |
| Dec. 16–17 | 10.02 | (1.54) | ...... | ...... | 2,179 | (226) | (87) | 1,866 |
| Dec. 17–18 | 12.76 | (1.54) | 12.10 | − .88 | 2,289 | (226) | 97 | 1,966 |
| Dec. 18–19 | 11.71 | (1.54) | 13.01 | −2.84 | 2,282 | (226) | 104 | 1,952 |
| Dec. 19–20[2] | 9.97 | (1.54) | 9.55 | −1.12 | 2,134 | (226) | 76 | 1,832 |
| Av. Dec. 3–20 | 10.39 | ...... | 10.24 | ...... | ...... | ...... | ...... | 2,005 |
| 1918. | | | | | | | | |
| Jan. 5– 6 | 0.00 | (1.05) | 7.03 | −8.08 | 0,000 | (152) | 56 | −208 |
| Jan. 6– 7 | 0.00 | (1.05) | 8.07 | −9.12 | 0,000 | (152) | 65 | −217 |
| Jan. 7– 8 | 7.95 | (1.05) | 10.24 | −3.34 | 1,657 | (152) | 82 | 1,423 |
| Jan. 8– 9 | 14.18 | (1.05) | 10.27 | +2.86 | 2,712 | (152) | 82 | 2,478 |
| Jan. 9–10 | 7.83 | (1.05) | 9.90 | −3.12 | 1,343 | (152) | 79 | 1,112 |
| Jan. 10–11 | 7.22 | (1.05) | 9.31 | −3.14 | 1,349 | (152) | 74 | 1,123 |
| Jan. 11–12 | 7.53 | (1.05) | 9.39 | −2.91 | 1,174 | (152) | 75 | 947 |
| Jan. 12–13 | 8.46 | (1.05) | 8.36 | − .95 | 1,796 | (152) | 67 | 1,577 |
| Av. Jan. 5–13 | 6.65 | ...... | 9.07 | ...... | ...... | ...... | ...... | 1,083 |

[1] Computed; see table 33, p. 269. [2] Dec. 20, 1917–Jan. 6, 1918 (inclusive), Christmas recess.

TABLE 51.—*Nitrogen balance and energy available to body*—OTTO A. GULLICKSON—continued.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine. (N×8.0). | |
| 1918—*continued.* | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Reduced diet—*cont.* | | | | | | | | |
| Jan. 13–14 | [1]28.47 | (1.05) | 6.81 | +20.61 | [1]5,264 | (152) | 54 | 5,058 |
| Jan. 14–15 | 7.78 | 1.05 | 7.99 | −1.26 | 1,439 | 152 | 64 | 1,223 |
| Jan. 15–16 | 5.46 | 1.05 | 7.47 | −3.06 | 965 | 152 | 60 | 753 |
| Jan. 16–17 | 6.35 | 1.05 | 7.74 | −2.44 | 1,278 | 152 | 62 | 1,064 |
| Jan. 17–18 | 0.00 | 1.05 | 6.08 | −7.13 | 24 | 152 | 49 | −177 |
| Jan. 18–19 | 0.00 | 1.05 | 9.06 | −10.11 | 24 | 152 | 72 | −200 |
| Jan. 19–20 | 8.46 | 1.05 | 10.57 | −3.16 | 1,772 | 152 | 85 | 1,535 |
| Jan. 20–21 | 5.73 | 1.05 | 8.31 | −3.63 | 1,495 | 152 | 66 | 1,277 |
| Jan. 21–22 | 6.82 | 1.05 | 7.99 | −2.22 | 1,366 | 152 | 64 | 1,150 |
| Jan. 22–23 | 8.10 | 1.05 | 8.11 | −1.06 | 1,441 | 152 | 65 | 1,224 |
| Jan. 23–24 | 6.36 | 1.05 | 8.02 | −2.71 | 1,321 | 152 | 64 | 1,105 |
| Jan. 24–25 | 9.04 | 1.05 | 7.71 | + .28 | 1,779 | 152 | 62 | 1,565 |
| Jan. 25–26 | 8.96 | 1.05 | 9.57 | −1.66 | 1,979 | 152 | 77 | 1,750 |
| Jan. 26–27 | 10.51 | 1.05 | 9.46 | ±0.00 | 2,163 | 152 | 76 | 1,935 |
| Jan. 27–28 | 9.62 | 1.05 | 9.00 | − .43 | 2,421 | 152 | 72 | 2,197 |
| Jan. 28–29 | 10.74 | 1.05 | 9.27 | + .42 | 2,002 | 152 | 74 | 1,776 |
| Jan. 29–30 | 11.25 | 1.05 | 8.93 | +1.27 | 2,086 | 152 | 71 | 1,863 |
| Jan. 30–31 | 9.94 | (1.05) | 8.86 | + .03 | 2,174 | (152) | 71 | 1,951 |
| Jan. 31–Feb. 1 | 12.55 | (1.05) | 7.95 | +3.55 | 2,130 | (152) | 64 | 1,914 |
| Feb. 1– 2 | 16.56 | (1.05) | 8.28 | +7.23 | 3,001 | (152) | 66 | 2,783 |
| Feb. 2– 3 | 8.52 | (1.05) | 6.83 | + .64 | 1,827 | (152) | 55 | 1,620 |
| Av. Jan. 13–Feb. 3. | 9.11 | ....... | 8.29 | ....... | ....... | ...... | ........ | 1,607 |

[1] Computed; see table 33, p. 269.

TABLE 51a.—*Nitrogen in urine during Christmas recess*—OTTO A. GULLICKSON.

| Date. | Nitrogen in urine per 24 hours. | Date. | Nitrogen in urine per 24 hours. |
|---|---|---|---|
| 1917. | *gm.* | 1917. | *gm.* |
| Dec. 20–21 | 9.31 | Dec. 28–29 | 9.85 |
| Dec. 21–22 | 7.58 | Dec. 29–30 | 11.20 |
| Dec. 22–23 | 7.31 | Dec. 30–31 | 10.49 |
| Dec. 23–24 | 9.75 | Dec. 31–Jan. 1 | 9.02 |
| Dec. 24–25 | 13.56 | 1918. | |
| Dec. 25–26 | 14.66 | Jan. 1– 2 | 8.92 |
| Dec. 26–27 | 11.54 | Jan. 2– 3 | 7.26 |
| Dec. 27–28 | 8.63 | Jan. 3– 4 | 13.48 |
| | | Jan. 4– 5 | 8.28 |

TABLE 52.—*Nitrogen balance and energy available to body*—KIRK G. MONTAGUE.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1917. | gm. | gm. | gm. | gm. | cals. | cals. | cals. | cals. |
| Normal diet: | | | | | | | | |
| Sept. 27–28 | ...... | ...... | 12.27 | ...... | ...... | ...... | ...... | ...... |
| Sept. 28–29 | ...... | ...... | 11.66 | ...... | ...... | ...... | ...... | ...... |
| Sept. 29–30 | ...... | ...... | 8.96 | ...... | ...... | ...... | ...... | ...... |
| Sept. 30–Oct. 1 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Oct. 1– 2 | 16.55 | 1.59 | 13.85 | +1.11 | 3,588 | 148 | 111 | 3,329 |
| Oct. 2– 3 | 14.93 | 1.59 | 7.30 | +6.04 | 2,974 | 148 | 58 | 2,768 |
| Oct. 3– 4 | 15.54 | 1.59 | 17.38 | −3.43 | 3,656 | 148 | 139 | 3,369 |
| Av. Oct. 1–4 | 15.67 | ...... | 12.84 | ...... | ...... | ...... | ...... | 3,155 |
| Reduced diet: | | | | | | | | |
| Oct. 4– 5 | 10.46 | (1.41) | 7.03 | +2.02 | 2,296 | (142) | 56 | 2,098 |
| Oct. 5– 6 | 11.85 | (1.41) | 12.59 | −2.15 | 2,111 | (142) | 101 | 1,868 |
| Oct. 6– 7 | 10.87 | (1.41) | 14.19 | −4.73 | 2,537 | (142) | 114 | 2,281 |
| Oct. 7– 8 | 10.00 | (1.41) | 12.89 | −4.30 | 2,123 | (142) | 103 | 1,878 |
| Oct. 8– 9 | 13.82 | 1.22 | 11.64 | + .96 | 2,371 | 135 | 93 | 2,143 |
| Oct. 9–10 | 12.21 | 1.22 | 11.10 | − .11 | 2,191 | 135 | 89 | 1,967 |
| Oct. 10–11 | 12.30 | 1.22 | 13.49 | −2.41 | 2,350 | 135 | 108 | 2,107 |
| Oct. 11–12 | 11.27 | 1.22 | 11.34 | −1.29 | 2,401 | 135 | 91 | 2,175 |
| Oct. 12–13 | 12.39 | (1.23) | 12.64 | −1.48 | 2,705 | (149) | 101 | 2,455 |
| Oct. 13–14 | 9.81 | (1.23) | 12.22 | −3.64 | 2,322 | (149) | 98 | 2,075 |
| Oct. 14–15 | [1]12.29 | ...... | ...... | ...... | [1]2,153 | (149) | (90) | 1,914 |
| Av. Oct. 4–15 | 11.57 | ...... | 11.91 | ...... | ...... | ...... | ...... | 2,067 |
| Oct. 15–16 | 11.13 | (1.23) | 10.24 | − .34 | 1,982 | (149) | 82 | 1,751 |
| Oct. 16–17 | 13.05 | (1.23) | 12.73 | − .91 | 2,182 | (149) | 102 | 1,931 |
| Oct. 17–18 | 10.36 | 1.24 | 10.62 | −1.50 | 1,859 | 162 | 85 | 1,612 |
| Oct. 18–19 | 14.75 | 1.24 | 12.02 | +1.49 | 2,580 | 162 | 96 | 2,322 |
| Oct. 19–20 | 9.99 | 1.24 | 10.44 | −1.69 | 1,729 | 162 | 84 | 1,483 |
| Oct. 20–21 | 10.41 | 1.24 | 12.58 | −3.41 | 2,043 | 162 | 101 | 1,780 |
| Oct. 21–22 | 9.71 | (1.11) | 8.83 | − .23 | 2,377 | (144) | 71 | 2,162 |
| Oct. 22–23 | 9.50 | (1.11) | 9.52 | −1.13 | 1,737 | (144) | 76 | 1,517 |
| Oct. 23–24 | 11.15 | (1.11) | 10.38 | − .34 | 2,196 | (144) | 83 | 1,969 |
| Oct. 24–25 | 13.26 | (1.11) | 8.73 | +3.42 | 2,450 | (144) | 70 | 2,236 |
| Oct. 25–26 | 8.46 | (1.11) | 9.99 | −2.64 | 1,500 | (144) | 80 | 1,276 |
| Oct. 26–27 | 10.62 | (1.11) | 10.32 | − .81 | 2,013 | (144) | 83 | 1,786 |
| Oct. 27–28 | 9.03 | (1.11) | 11.32 | −3.40 | 1,869 | (144) | 91 | 1,634 |
| Oct. 28–29 | [2]12.29 | ...... | ...... | ...... | [2]2,153 | (144) | (95) | 1,914 |
| Oct. 29–30 | 12.04 | (1.11) | 12.39 | −1.46 | 2,038 | (144) | 99 | 1,795 |
| Oct. 30–31 | 12.64 | (1.11) | 11.90 | − .37 | 1,896 | (144) | 95 | 1,657 |
| Oct. 31–Nov. 1 | 9.60 | .98 | 12.02 | −3.40 | 1,866 | 126 | 96 | 1,644 |
| Av. Oct. 15–Nov. 1. | 11.06 | ...... | 10.88 | ...... | ...... | ...... | ...... | 1,792 |
| Nov. 1– 2 | 9.52 | .98 | 11.18 | −2.64 | 1,570 | 126 | 89 | 1,355 |
| Nov. 2– 3 | 10.55 | .98 | 11.11 | −1.54 | 1,961 | 126 | 89 | 1,746 |
| Nov. 3– 4 | 8.33 | .98 | ...... | ...... | 1,691 | 126 | (89) | 1,476 |
| Nov. 4– 5 | 8.61 | (1.16) | 10.98 | −3.53 | 1,774 | (148) | 88 | 1,538 |
| Nov. 5– 6 | 9.59 | (1.16) | 10.99 | −2.56 | 1,468 | (148) | 88 | 1,232 |
| Nov. 6– 7 | 9.95 | (1.16) | 10.34 | −1.55 | 1,904 | (148) | 83 | 1,673 |
| Nov. 7– 8 | 10.40 | (1.16) | 10.74 | −1.50 | 2,059 | (148) | 86 | 1,825 |
| Nov. 8– 9 | 8.10 | (1.16) | 10.60 | −3.66 | 1,567 | (148) | 85 | 1,334 |

[1] Assumed. [2] Computed; see table 33, p. 269.

TABLE 52.—*Nitrogen balance and energy available to body*—KIRK G. MONTAGUE—continued.

[1] Computed; see table 33, p. 269.
[2] Nov. 30–Dec. 2 (inclusive), Thanksgiving recess.
[3] Dec. 20, 1917–Jan. 6, 1918 (inclusive), Christmas recess.

TABLE 52.—*Nitrogen balance and energy available to body*—KIRK G. MONTAGUE—continued.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1918—*continued.* | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Reduced diet—*cont.* | | | | | | | | |
| Jan. 7– 8[1] | 13.56 | (1.55) | 10.60 | +1.41 | 2,425 | (188) | 85 | 2,152 |
| Jan. 8– 9 | 13.86 | (1.55) | 7.50 | +4.81 | 2,676 | (188) | 60 | 2,428 |
| Jan. 9–10 | 12.06 | (1.55) | 12.16 | −1.65 | 2,005 | (188) | 97 | 1,720 |
| Jan. 10–11 | 10.98 | (1.55) | 11.10 | −1.67 | 2,128 | (188) | 89 | 1,851 |
| Jan. 11–12 | 7.21 | (1.55) | 11.40 | −5.74 | 1,125 | (188) | 91 | 846 |
| Jan. 12–13 | 8.46 | (1.55) | 12.37 | −5.46 | 1,788 | (188) | 99 | 1,501 |
| Jan. 13–14 | [2]15.80 | (1.55) | 10.71 | +3.54 | [2]3,955 | (188) | 86 | 3,681 |
| Jan. 14–15 | 6.08 | 1.55 | 8.47 | −3.94 | 1,240 | 188 | 68 | 984 |
| Av. Jan. 7–15 | 11.00 | ....... | 10.54 | ....... | ....... | ....... | ....... | 1,895 |
| Jan. 15–16 | 10.45 | 1.55 | 9.20 | − .30 | 1,841 | 188 | 74 | 1,579 |
| Jan. 16–17 | 9.99 | 1.55 | 9.19 | − .75 | 1,828 | 188 | 74 | 1,566 |
| Jan. 17–18 | 11.02 | 1.55 | 11.82 | −2.35 | 1,762 | 188 | 95 | 1,479 |
| Jan. 18–19 | 11.00 | 1.55 | 11.10 | −1.65 | 1,914 | 188 | 89 | 1,637 |
| Jan. 19–20 | 10.95 | 1.55 | 8.37 | +1.03 | 2,264 | 188 | 67 | 2,009 |
| Jan. 20–21 | 11.07 | 1.55 | 12.36 | −2.84 | 2,348 | 188 | 99 | 2,061 |
| Jan. 21–22 | 12.93 | 1.55 | 11.38 | ±0.00 | 2,218 | 188 | 91 | 1,939 |
| Jan. 22–23 | 15.23 | 1.55 | 10.91 | +2.77 | 2,683 | 188 | 87 | 2,408 |
| Jan. 23–24 | 15.73 | 1.55 | 12.47 | +1.71 | 3,327 | 188 | 100 | 3,039 |
| Jan. 24–25 | 12.66 | 1.55 | 8.66 | +2.45 | 2,145 | 188 | 69 | 1,888 |
| Jan. 25–26 | 10.97 | 1.55 | 11.36 | −1.94 | 2,330 | 188 | 91 | 2,051 |
| Jan. 26–27 | 11.00 | 1.55 | 14.22 | −4.77 | 2,261 | 188 | 114 | 1,959 |
| Jan. 27–28 | 9.11 | 1.55 | 11.36 | −3.80 | 1,749 | 188 | 91 | 1,470 |
| Jan. 28–29 | 12.44 | 1.55 | 12.38 | −1.49 | 2,262 | 188 | 99 | 1,975 |
| Jan. 29–30 | 21.68 | 1.55 | 12.57 | +7.56 | 3,768 | 188 | 101 | 3,479 |
| Jan. 30–31 | 12.01 | (1.55) | 12.39 | −1.93 | 2,719 | (188) | 99 | 2,432 |
| Jan. 31– Feb. 1 | 19.83 | (1.55) | 11.92 | +6.36 | 3,325 | (188) | 95 | 3,042 |
| Feb. 1– 2 | 16.56 | (1.55) | 13.39 | +1.62 | 2,977 | (188) | 107 | 2,682 |
| Feb. 2– 3 | 8.61 | (1.55) | 9.43 | −2.37 | 1,967 | (188) | 75 | 1,706 |
| Av. Jan. 15–Feb. 3 | 12.80 | ....... | 11.29 | ....... | ....... | ....... | ....... | 2,126 |

[1] On Jan. 5 and 6 subject had no food. [2] Computed; see table 33, p. 269.

TABLE 53.—*Nitrogen balance and energy available to body*—HENRY A. MOYER.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1917. | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Normal diet: | | | | | | | | |
| Sept. 27–28 | ....... | ....... | 13.69 | ....... | ....... | ....... | ....... | ....... |
| Sept. 28–29 | ....... | ....... | 10.06 | ....... | ....... | ....... | ....... | ....... |
| Sept. 29–30 | ....... | ....... | 6.28 | ....... | ....... | ....... | ....... | ....... |
| Sept. 30–Oct. 1 | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... |
| Oct. 1– 2 | 14.98 | 1.51 | 10.97 | +2.50 | 3,345 | 152 | 88 | 3,105 |
| Oct. 2– 3 | 14.93 | 1.51 | 13.36 | + .06 | 2,974 | 152 | 107 | 2,715 |
| Oct. 3– 4 | 15.54 | 1.51 | 12.64 | +1.39 | 3,656 | 152 | 101 | 3,403 |
| Av. Oct. 1–4 | 15.15 | ....... | 12.32 | ....... | ....... | ....... | ....... | 3,074 |

TABLE 53.—*Nitrogen balance and energy available to body*—HENRY A. MOYER—continued.

[1] Assumed. [2] Computed; see table 23, p. 269.

TABLE 53.—*Nitrogen balance and energy available to body*—HENRY A. MOYER—continued.

[1] Dec. 20, 1917–Jan. 6, 1918 (inclusive), Christmas recess. [2] Computed; see table 33, p. 269.

TABLE 53.—*Nitrogen balance and energy available to body*—HENRY A. MOYER—continued.

TABLE 54.—*Nitrogen balance and energy available to body*—ALLEN S. PEABODY.

[1] Assumed.

TABLE 54.—*Nitrogen balance and energy available to body*—ALLEN S. PEABODY—continued.

[1] Nov. 29–Dec. 2 (inclusive), Thanksgiving recess; nitrogen in urine Nov. 30–Dec. 1, 7.63 gms.
[2] Computed; see table 33, p. 269.

TABLE 54.—*Nitrogen balance and energy available to body*—ALLEN S. PEABODY—continued.

[1] Dec. 20, 1917–Jan. 6, 1918 (inclusive), Christmas recess. [2] Computed; see table 32, p. 269.

TABLE 55.—*Nitrogen balance and energy available to body*—R. WALLACE PECKHAM.

[1] Assumed. [2] Computed; see table 33, p. 269.

TABLE 55.—*Nitrogen balance and energy available to body*—R. WALLACE PECKHAM—continued.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1917—*continued.* | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Reduced diet—*cont.* | | | | | | | | |
| Nov. 10–11 | 9.17 | .96 | 14.80 | −6.59 | 1,635 | 143 | 118 | 1,374 |
| Nov. 11–12 | [2]11.69 | .96 | ....... | ....... | [2]2,650 | 143 | (104) | 2,403 |
| Nov. 12–13 | 8.37 | .96 | 11.07 | −3.66 | 1,784 | 143 | 89 | 1,552 |
| Nov. 13–14 | 11.66 | .96 | 12.07 | −1.37 | 1,909 | 143 | 97 | 1,669 |
| Nov. 14–15 | 10.83 | .96 | 12.72 | −2.85 | 1,676 | 143 | 102 | 1,431 |
| Nov. 15–16 | 8.09 | .96 | 11.78 | −4.65 | 1,511 | 143 | 94 | 1,274 |
| Nov. 16–17 | 10.07 | .96 | 11.31 | −2.20 | 1,382 | 143 | 90 | 1,149 |
| Nov. 17–18 | 8.32 | .96 | 10.08 | −2.72 | 1,566 | 143 | 81 | 1,342 |
| Nov. 18–19 | 7.88 | .96 | 11.72 | −4.80 | 1,445 | 143 | 94 | 1,208 |
| Nov. 19–20 | 10.44 | .96 | 11.84 | −2.36 | 1,990 | 143 | 95 | 1,752 |
| Nov. 20–21 | 10.85 | .96 | 9.60 | + .29 | 1,771 | 143 | 77 | 1,551 |
| Nov. 21–22 | 6.28 | .96 | 17.90 | −12.58 | 1,339 | 143 | 143 | 1,053 |
| Nov. 22–23 | 8.70 | .96 | 10.43 | −2.69 | 1,911 | 143 | 83 | 1,685 |
| Nov. 23–24 | 8.94 | .96 | 9.90 | −1.92 | 1,844 | 143 | 79 | 1,622 |
| Nov. 24–25 | 9.01 | .96 | 7.93 | + .12 | 1,664 | 143 | 63 | 1,458 |
| Nov. 25–26 | [2]17.44 | .96 | ....... | ....... | [2]3,541 | 143 | (81) | 3,317 |
| Nov. 26–27 | 9.10 | .96 | ....... | ....... | 1,646 | 143 | (81) | 1,422 |
| Nov. 27–28 | 9.56 | .96 | 12.22 | −3.62 | 1,688 | 143 | 98 | 1,447 |
| Nov. 28–29 | 6.64 | .96 | 16.28 | −10.60 | 1,568 | 143 | 130 | 1,295 |
| Av. Oct. 29–Nov. 29. | 9.43 | ....... | 11.68 | ....... | ....... | ....... | ....... | 1,507 |
| Nov. 29–30 | ....... | 1.44 | 14.87 | ....... | ....... | 220 | ....... | ....... |
| Nov. 30–Dec. 1 | ....... | 1.44 | 15.83 | ....... | ....... | 220 | ....... | ....... |
| Dec. 1– 2 | ....... | 1.44 | 11.39 | ....... | ....... | 220 | ....... | ....... |
| Dec. 2– 3 | ....... | 1.44 | 12.23 | ....... | ....... | 220 | ....... | ....... |
| Dec. 3– 4 | 8.70 | 1.44 | 7.27 | − .01 | 1,685 | 220 | 58 | 1,407 |
| Dec. 4– 5 | 12.81 | 1.44 | 12.95 | −1.58 | 2,236 | 220 | 104 | 1,912 |
| Dec. 5– 6 | 9.75 | 1.44 | 12.40 | −4.09 | 1,927 | 220 | 99 | 1,608 |
| Dec. 6– 7 | 10.41 | 1.44 | 11.55 | −2.58 | 2,112 | 220 | 92 | 1,800 |
| Dec. 7– 8 | 8.45 | 1.44 | 11.35 | −4.34 | 1,840 | 220 | 91 | 1,529 |
| Dec. 8– 9 | 8.64 | 1.44 | 10.17 | −2.97 | 1,745 | 220 | 81 | 1,444 |
| Av. Dec. 3–9 | 9.79 | ....... | 10.95 | ....... | ....... | ....... | ....... | 1,617 |
| Dec. 9–10 | [2]20.15 | 1.44 | ....... | ....... | [2]4,414 | 220 | (94) | 4,100 |
| Dec. 10–11 | 9.63 | 1.08 | 13.28 | −4.73 | 2,261 | 179 | 106 | 1,976 |
| Dec. 11–12 | 10.75 | 1.08 | 9.67 | ±0.00 | 2,119 | 179 | 77 | 1,863 |
| Dec. 12–13 | 12.02 | 1.08 | 10.90 | + .04 | 2,329 | 179 | 87 | 2,063 |
| Dec. 13–14 | 10.34 | 1.08 | 11.51 | −2.25 | 2,085 | 179 | 92 | 1,814 |
| Dec. 14–15 | 8.48 | 1.08 | 10.21 | −2.81 | 2,150 | 179 | 82 | 1,889 |
| Dec. 15–16 | 10.51 | (1.08) | ....... | ....... | 2,652 | (179) | (84) | 2,389 |
| Dec. 16–17 | 9.55 | (1.08) | ....... | ....... | 2,091 | (179) | (84) | 1,828 |
| Dec. 17–18 | 12.76 | (1.08) | 10.76 | + .92 | 2,392 | (179) | 86 | 2,127 |
| Dec. 18–19 | 11.71 | (1.08) | 11.67 | −1.04 | 2,345 | (179) | 93 | 2,073 |
| Dec. 19–20[1] | 10.43 | (1.08) | 11.81 | −2.46 | 2,306 | (179) | 94 | 2,033 |
| Av. Dec. 9–20 | 11.48 | ....... | 11.23 | ....... | ....... | ....... | ....... | 2,196 |
| 1918. | | | | | | | | |
| Jan. 5– 6 | 00.00 | ( .96) | 11.89 | −12.85 | 0,000 | (134) | 95 | −229 |
| Jan. 6– 7 | 00.00 | ( .96) | 9.62 | −10.58 | 0,000 | (134) | 77 | −211 |
| Jan. 7– 8 | 13.08 | ( .96) | 12.58 | − .46 | 2,255 | (134) | 101 | 2,020 |
| Jan. 8– 9 | 13.49 | ( .96) | 13.36 | − .83 | 2,447 | (134) | 107 | 2,206 |
| Jan. 9–10 | 7.19 | ( .96) | 7.85 | −1.62 | 1,219 | (134) | 63 | 1,022 |

[1] Dec. 20, 1917–Jan. 6, 1918 (inclusive), Christmas recess. [2] Computed; see table 33, p. 269.

TABLE 55.—*Nitrogen balance and energy available to body*—R. WALLACE PECKHAM—continued.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1918—*continued.* | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Reduced diet—*cont.* | | | | | | | | |
| Jan. 10–11.......... | 8.97 | ( .96) | 11.29 | −3.28 | 1,658 | (134) | 90 | 1,434 |
| Jan. 11–12.......... | 8.84 | ( .96) | 11.97 | −4.09 | 1,367 | (134) | 96 | 1,137 |
| Jan. 12–13.......... | 10.76 | ( .96) | 12.45 | −2.65 | 2,131 | (134) | 100 | 1,897 |
| Jan. 13–14.......... | [1]11.30 | ( .96) | 13.26 | −2.92 | [1]2,900 | (134) | 106 | 2,660 |
| Jan. 14–15.......... | 8.10 | .96 | 11.30 | −4.16 | 1,464 | 134 | 90 | 1,240 |
| Jan. 15–16.......... | 6.82 | .96 | 8.18 | −2.32 | 1,221 | 134 | 65 | 1,022 |
| Jan. 16–17.......... | 11.51 | .96 | 8.33 | +2.22 | 2,027 | 134 | 67 | 1,826 |
| Jan. 17–18.......... | 6.27 | .96 | 9.92 | −4.61 | 969 | 134 | 79 | 756 |
| Jan. 18–19.......... | 11.00 | .96 | 11.56 | −1.52 | 1,898 | 134 | 92 | 1,672 |
| Jan. 19–20.......... | 4.22 | .96 | 12.02 | −8.76 | 1,235 | 134 | 96 | 1,005 |
| Av. Jan. 5–20...... | 8.10 | ....... | 11.04 | ....... | ....... | ....... | ....... | 1,326 |
| Jan. 20–21.......... | 8.94 | .96 | 8.11 | − .13 | 1,886 | 134 | 65 | 1,687 |
| Jan. 21–22.......... | 8.28 | .96 | 8.59 | −1.27 | 1,435 | 134 | 69 | 1,232 |
| Jan. 22–23.......... | 9.41 | .96 | 9.56 | −1.11 | 1,340 | 134 | 76 | 1,130 |
| Jan. 23–24.......... | 7.85 | .96 | 9.54 | −2.65 | 1,647 | 134 | 76 | 1,437 |
| Jan. 24–25.......... | 9.21 | .96 | 9.51 | −1.26 | 1,855 | 134 | 76 | 1,645 |
| Jan. 25–26.......... | 8.03 | .96 | 9.67 | −2.60 | 1,647 | 134 | 77 | 1,436 |
| Jan. 26–27.......... | 9.21 | .96 | 10.40 | −2.15 | 1,992 | 134 | 83 | 1,775 |
| Jan. 27–28.......... | 9.11 | .96 | 11.95 | −3.80 | 1,733 | 134 | 96 | 1,503 |
| Jan. 28–29.......... | 8.49 | .96 | 9.19 | −1.66 | 1,524 | 134 | 74 | 1,316 |
| Jan. 29–30.......... | 11.25 | .96 | 9.20 | +1.09 | 2,062 | 134 | 74 | 1,854 |
| Jan. 30–31.......... | 9.68 | ( .96) | 9.68 | − .96 | 2,092 | (134) | 77 | 1,881 |
| Jan. 31–Feb. 1...... | 12.55 | ( .96) | 11.40 | + .19 | 2,098 | (134) | 91 | 1,873 |
| Feb. 1– 2.......... | 13.48 | ( .96) | 9.85 | +2.67 | 2,507 | (134) | 79 | 2,294 |
| Feb. 2– 3.......... | 8.52 | ( .96) | 10.32 | −2.76 | 1,814 | (134) | 83 | 1,597 |
| Av. Jan. 20–Feb. 3. | 9.57 | ....... | 9.78 | ....... | ....... | ....... | ....... | 1,619 |

[1] Computed; see table 33, p. 269.

TABLE 55a.—*Nitrogen in urine during Christmas recess*—R. WALLACE PECKHAM.

| Date. | Nitrogen in urine per 24 hours. | Date. | Nitrogen in urine per 24 hours. |
|---|---|---|---|
| 1917. | *gm.* | 1918. | *gm.* |
| Dec. 20–21..... | 14.07 | Jan. 1–2....... | 15.70 |
| Dec. 21–22..... | 10.81 | Jan. 2–3....... | 17.59 |
| Dec. 22–29[1].... | ............ | Jan. 3–4....... | 13.73 |
| Dec. 30–31..... | 7.96 | Jan. 4–5....... | 9.55 |

[1] Inclusive; no record.

TABLE 56.—*Nitrogen balance and energy available to body*—WESLEY G. SPENCER.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1917—*continued.* | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Normal diet: | | | | | | | | |
| Sept. 27–28 | ...... | ...... | 14.63 | ...... | ...... | ...... | ...... | ...... |
| Sept. 28–29 | ...... | ...... | 14.81 | ...... | ...... | ...... | ...... | ...... |
| Sept. 29–30 | ...... | ...... | 14.56 | ...... | ...... | ...... | ...... | ...... |
| Sept. 30–Oct. 1 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Oct. 1– 2 | 17.79 | 1.52 | 13.85 | +2.42 | 3,706 | 122 | 111 | 3,473 |
| Oct. 2– 3 | 14.93 | 1.52 | 14.70 | −1.29 | 2,974 | 122 | 118 | 2,734 |
| Oct. 3– 4 | 15.54 | 1.52 | 14.49 | − .47 | 3,656 | 122 | 116 | 3,418 |
| Av. Oct. 1–4 | 16.09 | ...... | 14.35 | ...... | ...... | ...... | ...... | 3,208 |
| Reduced diet: | | | | | | | | |
| Oct. 4– 5 | 10.46 | (1.43) | 11.92 | −2.89 | 2,304 | (134) | 95 | 2,075 |
| Oct. 5– 6 | 11.85 | (1.43) | 13.69 | −3.27 | 2,119 | (134) | 110 | 1,875 |
| Oct. 6– 7 | 10.87 | (1.43) | 12.47 | −3.03 | 2,545 | (134) | 100 | 2,311 |
| Oct. 7– 8 | 9.65 | (1.43) | 10.38 | −2.16 | 2,111 | (134) | 83 | 1,894 |
| Oct. 8– 9 | 13.82 | 1.33 | 12.93 | − .44 | 2,379 | 146 | 103 | 2,130 |
| Oct. 9–10 | 12.21 | 1.33 | 12.88 | −2.00 | 2,199 | 146 | 103 | 1,950 |
| Oct. 10–11 | 12.19 | 1.33 | 12.99 | −2.13 | 2,337 | 146 | 104 | 2,087 |
| Oct. 11–12 | 11.11 | 1.33 | 11.69 | −1.91 | 2,380 | 146 | 94 | 2,140 |
| Oct. 12–13 | 12.39 | (1.09) | 11.35 | − .05 | 2,713 | (129) | 91 | 2,493 |
| Oct. 13–14 | 9.59 | (1.09) | 12.24 | −3.74 | 2,289 | (129) | 98 | 2,062 |
| Oct. 14–15 | [1]14.73 | ...... | ...... | ...... | [1]3,248 | (129) | (97) | 3,022 |
| Av. Oct. 4–15 | 11.72 | ...... | 12.25 | ...... | ...... | ...... | ...... | 2,185 |
| Oct. 15–16 | 11.13 | (1.09) | 11.92 | −1.88 | 1,998 | (129) | 95 | 1,774 |
| Oct. 16–17 | 13.05 | (1.09) | 12.69 | − .73 | 2,174 | (129) | 102 | 1,943 |
| Oct. 17–18 | 10.36 | .84 | 12.37 | −2.85 | 1,859 | 112 | 99 | 1,648 |
| Oct. 18–19 | 14.59 | .84 | 12.93 | + .82 | 2,567 | 112 | 103 | 2,352 |
| Oct. 19–20 | 9.84 | .84 | 11.76 | −2.76 | 1,708 | 112 | 94 | 1,502 |
| Oct. 20–21 | 9.78 | .84 | 11.80 | −2.86 | 1,876 | 112 | 94 | 1,670 |
| Oct. 21–22 | 9.40 | ( .97) | 11.94 | −3.51 | 2,327 | (125) | 96 | 2,106 |
| Oct. 22–23 | 8.87 | ( .97) | 10.55 | −2.65 | 1,621 | (125) | 84 | 1,412 |
| Oct. 23–24 | 10.37 | ( .97) | 11.25 | −1.85 | 2,067 | (125) | 90 | 1,852 |
| Oct. 24–25 | 13.11 | ( .97) | 11.75 | + .39 | 2,430 | (125) | 94 | 2,211 |
| Oct. 25–26 | 8.15 | ( .97) | 9.81 | −2.63 | 1,458 | (125) | 78 | 1,255 |
| Oct. 26–27 | 10.62 | ( .97) | 12.21 | −2.56 | 2,021 | (125) | 98 | 1,798 |
| Oct. 27–28 | 8.40 | ( .97) | 11.75 | −4.32 | 1,761 | (125) | 94 | 1,542 |
| Oct. 28–29 | [2]14.73 | ...... | ...... | ...... | [2]3,248 | (125) | (94) | 3,029 |
| Av. Oct. 15–29 | 10.89 | ...... | 11.75 | ...... | ...... | ...... | ...... | 1,864 |
| Oct. 29–30 | 12.19 | ( .97) | 11.63 | − .41 | 2,082 | (125) | 93 | 1,864 |
| Oct. 30–31 | 12.18 | ( .97) | 13.07 | −1.86 | 1,826 | (125) | 105 | 1,596 |
| Oct. 31–Nov. 1 | 9.60 | 1.10 | 11.12 | −2.62 | 1,882 | 138 | 89 | 1,655 |
| Nov. 1– 2 | 9.52 | 1.10 | 12.25 | −3.83 | 1,578 | 138 | 98 | 1,342 |
| Nov. 2– 3 | 10.55 | 1.10 | 12.09 | −2.64 | 2,056 | 138 | 97 | 1,821 |
| Nov. 3– 4 | 8.33 | 1.10 | ...... | ...... | 1,762 | 138 | (94) | 1,530 |
| Nov. 4– 5 | 8.61 | (1.25) | 11.31 | −3.95 | 1,845 | (153) | 90 | 1,602 |
| Nov. 5– 6 | 9.59 | (1.25) | 13.05 | −4.71 | 1,555 | (153) | 104 | 1,298 |
| Nov. 6– 7 | 9.95 | (1.25) | 11.35 | −2.65 | 1,912 | (153) | 91 | 1,668 |
| Nov. 7– 8 | 11.02 | (1.25) | 11.55 | −1.78 | 2,199 | (153) | 92 | 1,954 |
| Nov. 8– 9 | 8.10 | (1.25) | 9.88 | −3.03 | 1,559 | (153) | 79 | 1,327 |
| Nov. 9–10 | 7.97 | (1.25) | 10.95 | −4.23 | 1,390 | (153) | 88 | 1,149 |
| Nov. 10–11 | 9.17 | (1.25) | 13.15 | −5.23 | 1,635 | (153) | 105 | 1,377 |
| Nov. 11–12 | [2]8.93 | ...... | ...... | ...... | [2]3,241 | (153) | (90) | 2,998 |
| Av. Oct. 29–Nov. 12 | 9.69 | ...... | 11.78 | ...... | ...... | ...... | ...... | 1,656 |

[1] Assumed. [2] Computed; see table 33, p. 269.

TABLE 56.—*Nitrogen balance and energy available to body*—WESLEY G. SPENCER—continued.

[1] Assumed.
[2] Computed; see table 33, p. 269.
[3] Nov. 30–Dec. 2 (inclusive), Thanksgiving recess.

TABLE 57.—*Nitrogen balance and energy available to body*—LESLIE J. TOMPKINS.

[1] Assumed. [2] Computed; see table 83, p. 269.

TABLE 57.—*Nitrogen* *to body*—LESLIE J. TOMPKINS—continued.

[1] Computed; see table 33, p. 269.
[2] Nov. 28–Dec. 2 (inclusive), Thanksgiving recess.
[3] Dec. 20, 1917–Jan. 11, 1918 (inclusive), Christmas recess.

TABLE 57.—*Nitrogen balance and energy available to body*—LESLIE J. TOMPKINS—continued.

| Date. | Nitrogen per 24 hours in— Food. | Feces. | Urine. | Nitrogen balance. | Energy per 24 hours of— Food. | Feces. | Urine (N×8.0). | Net energy. |
|---|---|---|---|---|---|---|---|---|
| 1918—*continued.* | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Reduced diet—*cont.* | | | | | | | | |
| Jan. 17–18 | 5.36 | .87 | 7.98 | −3.49 | 912 | 94 | 64 | 754 |
| Jan. 18–19 | 5.61 | .87 | 9.68 | −4.94 | 1,008 | 94 | 77 | 837 |
| Jan. 19–20 | 5.96 | .87 | 6.89 | −1.80 | 1,250 | 94 | 55 | 1,101 |
| Jan. 20–21 | 7.04 | .87 | 8.07 | −1.90 | 1,404 | 94 | 65 | 1,245 |
| Jan. 21–22 | 6.84 | .87 | 7.68 | −1.71 | 1,188 | 94 | 61 | 1,033 |
| Jan. 22–23 | 9.80 | .87 | 7.78 | +1.15 | 1,638 | 94 | 62 | 1,482 |
| Jan. 23–24 | 7.05 | .87 | 7.80 | −1.62 | 1,547 | 94 | 62 | 1,391 |
| Jan. 24–25 | 8.08 | .87 | 6.99 | + .22 | 1,650 | 94 | 56 | 1,500 |
| Av. Jan. 12–25 | 7.60 | ....... | 7.48 | ....... | ....... | ....... | ....... | 1,289 |
| Jan. 25–26 | 6.86 | .87 | 5.59 | + .40 | 1,798 | 94 | 45 | 1,659 |
| Jan. 26–27 | 8.30 | .87 | 6.92 | + .51 | 1,850 | 94 | 55 | 1,701 |
| Jan. 27–28 | 7.76 | .87 | 8.51 | −1.62 | 1,516 | 94 | 68 | 1,354 |
| Jan. 28–29 | 7.95 | .87 | 6.66 | + .42 | 1,429 | 94 | 53 | 1,282 |
| Jan. 29–30 | 10.45 | .87 | 7.25 | +2.33 | 1,957 | 94 | 58 | 1,805 |
| Jan. 30–31 | 9.12 | ( .87) | 8.92 | − .67 | 2,033 | ( 94) | 71 | 1,868 |
| Jan. 31–Feb. 1 | 11.75 | ( .87) | 8.59 | +2.29 | 1,973 | ( 94) | 69 | 1,810 |
| Feb. 1– 2 | 10.09 | ( .87) | 10.37 | −1.15 | 1,940 | ( 94) | 83 | 1,763 |
| Feb. 2– 3 | 7.11 | ( .87) | 6.54 | − .30 | 1,866 | ( 94) | 52 | 1,720 |
| Av. Jan. 25–Feb. 3 | 8.82 | ....... | 7.71 | ....... | ....... | ....... | ....... | 1,662 |

TABLE 58.—*Nitrogen balance and energy available to body*—RONALD T. VEAL.

| Date. | Nitrogen per 24 hours in— Food. | Feces. | Urine. | Nitrogen balance. | Energy per 24 hours of— Food. | Feces. | Urine (N×8.0). | Net energy. |
|---|---|---|---|---|---|---|---|---|
| 1917. | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Normal diet: | | | | | | | | |
| Sept. 27–28 | ....... | ....... | 16.33 | ....... | ....... | ....... | ....... | ....... |
| Sept. 28–29 | ....... | ....... | 17.21 | ....... | ....... | ....... | ....... | ....... |
| Sept. 29–30 | ....... | ....... | 12.70 | ....... | ....... | ....... | ....... | ....... |
| Sept. 30–Oct. 1 | ....... | ....... | ....... | ....... | ....... | ....... | ....... | ....... |
| Oct. 1– 2 | 16.25 | 1.19 | 15.24 | − .18 | 3,525 | 120 | 122 | 3,283 |
| Oct. 2– 3 | 14.93 | 1.19 | 13.41 | + .33 | 2,974 | 120 | 107 | 2,747 |
| Oct. 3– 4 | 15.54 | 1.19 | 13.00 | +1.35 | 2,656 | 120 | 104 | 2,432 |
| Av. Oct. 1–4 | 15.57 | ....... | 13.88 | ....... | ....... | ....... | ....... | 2,821 |
| Reduced diet: | | | | | | | | |
| Oct. 4– 5 | 10.46 | (1.11) | 12.82 | −3.47 | 2,304 | (122) | 103 | 2,079 |
| Oct. 5– 6 | 11.85 | (1.11) | 10.38 | + .36 | 2,119 | (122) | 83 | 1,914 |
| Oct. 6– 7 | 10.87 | (1.11) | 10.82 | −1.06 | 2,545 | (122) | 87 | 2,336 |
| Oct. 7– 8 | 9.14 | (1.11) | 11.31 | −3.28 | 2,062 | (122) | 90 | 1,850 |
| Oct. 8– 9 | 13.67 | 1.02 | 11.18 | +1.47 | 2,350 | 124 | 89 | 2,137 |
| Oct. 9–10 | 12.05 | 1.02 | 12.21 | −1.18 | 2,170 | 124 | 98 | 1,948 |
| Oct. 10–11 | 11.52 | 1.02 | 11.51 | −1.01 | 2,213 | 124 | 92 | 1,997 |
| Oct. 11–12 | 10.80 | 1.02 | 10.57 | − .79 | 2,322 | 124 | 85 | 2,113 |
| Oct. 12–13 | 12.01 | ( .92) | 11.30 | − .21 | 2,642 | (114) | 90 | 2,438 |
| Oct. 13–14 | 9.36 | ( .92) | 10.30 | −1.86 | 2,239 | (114) | 82 | 2,043 |
| Oct. 14–15 | [1]16.01 | ....... | ....... | ....... | [1]4,057 | (114) | (84) | 3,859 |
| Av. Oct. 4–15 | 11.61 | ....... | 11.24 | ....... | ....... | ....... | ....... | 2,247 |

[1] Assumed.

TABLE 58.—*Nitrogen balance and energy available to body*—RONALD T. VEAL—continued.

[1] Computed; see table 33, p. 269.

TABLE 58.—*Nitrogen balance and energy available to body*—RONALD T. VEAL—continued.

[1]Computed see table 33, p. 269. [2]Dec. 20, 1917–Jan. 6, 1918 (inclusive), Christmas recess.

NITROGEN BALANCE AND ENERGY AVAILABLE TO BODY, SQUAD B.

TABLE 59.—*Nitrogen balance and* *during period of reduced diet*—

TABLE *balance* *during period of reduced diet*—

TABLE 61.—*Nitrogen balance and energy available to body during period of reduced diet*—KARL Z. HOWLAND.

TABLE 62.—*Nitrogen balance and energy available to body during period of reduced diet*—ROBERT L. HAMMOND.

TABLE 63.—*Nitrogen balance and energy available to body during period of reduced diet*—HAROLD L. KIMBALL.

TABLE 64.—*Nitrogen balance and energy available to body during period of reduced diet*—ROBERT H. LONG.

TABLE 65.—*Nitrogen balance and energy available to body during period of reduced diet*—JOHN SCHRACK.

TABLE 66.—*Nitrogen balance and energy available to body during period of reduced diet*—ALFRED LIVINGSTONE.

| Date. | Nitrogen per 24 hours in— | | | Nitrogen balance. | Energy per 24 hours of— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine (N×8.0). | |
| 1918. | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Jan. 8–9 | 7.67 | (0.68) | 17.41 | −10.42 | 1,256 | (108) | 139 | 1,009 |
| 9–10 | 8.27 | ( .68) | 11.91 | −4.32 | 1,490 | (108) | 95 | 1,287 |
| 10–11 | 8.04 | ( .68) | 12.40 | −5.04 | 1,564 | (108) | 99 | 1,357 |
| 11–12 | 8.47 | ( .68) | 11.92 | −4.13 | 1,576 | (108) | 95 | 1,373 |
| 12–13 | 9.22 | ( .68) | 12.72 | −4.18 | 1,724 | (108) | 102 | 1,514 |
| 13–14 | 7.89 | ( .68) | 11.97 | −4.76 | 1,660 | (108) | 96 | 1,456 |
| 14–15 | 10.09 | ( .68) | 10.41 | −1.00 | 1,945 | (108) | 83 | 1,754 |
| 15–16 | 7.82 | .68 | ...... | ...... | 1,498 | 108 | 87 | 1,303 |
| 16–17 | 7.64 | .68 | 11.33 | −4.37 | 1,443 | 108 | 91 | 1,244 |
| 17–18 | 9.03 | .68 | 11.42 | −3.07 | 1,445 | 108 | 91 | 1,246 |
| 18–19 | 8.44 | .68 | 12.76 | −5.00 | 1,486 | 108 | 102 | 1,276 |
| 19–20 | 8.07 | .68 | 11.14 | −3.75 | 1,816 | 108 | 89 | 1,619 |
| 20–21 | 8.88 | .68 | 11.47 | −3.27 | 1,655 | 108 | 92 | 1,455 |
| 21–22 | 8.05 | .68 | 11.65 | −4.28 | 1,592 | 108 | 93 | 1,391 |
| 22–23 | 8.66 | .68 | 11.76 | −3.78 | 1,430 | 108 | 94 | 1,228 |
| 23–24 | 7.59 | ( .68) | 11.25 | −4.34 | 1,546 | (108) | 90 | 1,348 |
| 24–25 | 9.05 | ( .68) | 11.51 | −3.14 | 1,752 | (108) | 92 | 1,552 |
| 25–26 | 8.78 | ( .68) | 11.21 | −3.11 | 1,563 | (108) | 90 | 1,365 |
| 26–27 | 7.91 | ( .68) | 10.23 | −3.00 | 1,658 | (108) | 82 | 1,468 |
| 27–28 | 6.38 | ( .68) | 10 06 | −4.36 | 1,657 | (108) | 80 | 1,469 |
| Average | 8.30 | .68 | 11.82 | −4.17 | 1,588 | '08 | 94 | 1,386 |

TABLE 67.—*Nitrogen balance and energy available to body during period of reduced diet*—CHESTER D. SNELL.

TABLE 68.—*Nitrogen balance and energy available to body during period of reduced diet*—GEORGE H. THOMPSON.

TABLE 69.—*Nitrogen balance and energy available to body during period of reduced diet*—FLOYD M. VAN WAGNER.

TABLE 70.—*Nitrogen balance and energy available to body during period of reduced diet*—ELTON L. WILLIAMS.

The irregularities in the nitrogen intake have been pointed out in a previous section, as shown for the individual subjects at the beginning of the observations and for 2 weeks in December and from the average for the whole squad. These irregularities are strikingly shown in tables 46 to 58. The estimated intakes of nitrogen and energy for the uncontrolled days are also included in these tables, but are indicated by footnotes, since their mathematical accuracy is in doubt. They stand out prominently as the intakes of both nitrogen and calories are larger than on either the preceding or following days. The gain or loss of nitrogen for these uncontrolled days is not computed except for January 13–14, 1918. The estimations for nitrogen intake are, however, considered of sufficient accuracy to be included in any general averages which appear in the tables. Unfortunately, owing to the extremely cold winter and unsatisfactory transportation, some of the samples of urine for December 15, 16, and 17 were frozen, and hence the values for these days can not be given, and no estimate has been attempted. These days are omitted from any general consideration of the nitrogen balance. Although it was impossible to obtain the fecal nitrogen for the entire period, reference to table 37 (p. 293), and, indeed, tables 46 to 58, shows that the separation of feces was made with sufficient frequency to give a fairly uniform picture of the probable fecal nitrogen excretion for the whole experiment. In the detailed tables the interpolated values are placed in parentheses, all other values for feces being those actually determined. These determined values usually represent the average for a period of collection of feces of 3 to 16 days.

The general picture presented by every member of Squad A is a great predominance of minus figures for the nitrogen balance, after the first three preliminary days of unrestricted diet. Plus values rarely appear, except in the latter part of December and the latter part of January. Throughout the period of loss in weight there was evidently a pronounced tendency for each subject to lose nitrogen. During December, when an attempt was made to supply a sufficient number of calories to secure weight maintenance, the frequent appearance of positive figures indicates that with the higher caloric intake there was a smaller loss of nitrogen with a tendency towards equilibrium. During the last week in January this is particularly noticeable. A general statement may thus be made that for practically the entire experiment, save for these two periods, the subjects were losing body nitrogen, as shown by a comparison of the fecal and urinary nitrogen with the nitrogen in the food.

The total losses of nitrogen from the body shown by these men prior to January 28 are of interest, since in the last week of the experiment the caloric intake was considerably increased to hold the body-weight. The total losses of nitrogen from October 4, the initial day of the re-

duced diet, until January 27, inclusive, without regard to the cutaneous loss or to the uncontrolled days, has been computed for all of the subjects in Squad A and recorded in table 71. Special attention must

TABLE 71.—*Total loss of nitrogen and average daily loss of nitrogen, Squad A, October 4 to January 27, inclusive.*

| Subject. | Total loss of nitrogen. | No. of days. | Av. loss of nitrogen per day. |
|---|---|---|---|
| | *gm.* | | *gm.* |
| Bro...... | 153.48 | 83 | 1.85 |
| Can...... | 155.77 | 84 | 1.85 |
| Fre...... | 32.29 | 20 | 1.61 |
| Kon...... | 233.08 | 57 | 4.09 |
| Gar...... | 168.95 | 86 | 1.96 |
| Gul...... | 162.45 | 86 | 1.89 |
| Mon...... | 134.07 | 86 | 1.56 |
| Moy...... | 230.31 | 83 | 2.77 |
| Pea...... | 206.14 | 86 | 2.40 |
| Pec...... | 252.85 | 87 | 2.91 |
| Spe...... | 130.15 | 61 | 2.13 |
| Tom...... | 48.66 | 78 | 0.62 |
| Vea...... | 159.70 | 86 | 1.86 |

be paid to the number of days that the subjects were actually studied. Thus we have for *Fre* but 20 days, for *Kon*, 57 days, for *Spe*, 61 days, and for *Tom*, 78 days. The other men were studied from 83 to 87 days. Disregarding the value for *Fre*, we find that with the members of Squad A, who were longest studied, the total nitrogen loss ranges from a minimum of 48.66 grams with *Tom* to a maximum of 252.85 grams with *Pec*. Every member of the squad, other than *Fre* and *Tom*, lost more than 130 grams in this period, and 3 lost more than 230 grams. The average loss of nitrogen per day is given in the last column of the table and shows a minimum value of 0.62 gram with *Tom* and a maximum value of 4.09 grams with *Kon*. At least 10 men showed losses of over 1.8 grams per day. When it is considered that these losses continued in most instances for a period of 80 days or more, the total loss is really remarkable. The small loss recorded for *Fre* is accounted for by the fact that he was but 20 days on diet and needs no further discussion. The largest average loss, that of *Kon*, is possibly explained by the fact that he began late and was purposely put upon a very restricted diet in order to reduce the body-weight as rapidly as possible. The small loss with *Tom* is, in part, explained by his small body-weight as compared with the other subjects. His activity was also the least, and the total reduction in diet was not so low per kilogram of body-weight as with many of the other men. Furthermore, on account of his feeling of *malaise* throughout January, resulting from an operation during the Christmas recess, a rigid dietetic restriction did not seem possible with him. The difficulty experienced in lowering his body-

weight has been frequently commented upon in other parts of this report. The average loss per day for all men is, excluding *Fre*, 2.16 grams.

The losses in nitrogen for Squad B are given in a similar manner in table 72. These values also disregard cutaneous losses, which, probably, in this case should not be disregarded, since we have no compensating excess food to deal with. Although the nitrogen balance figures for Squad B are given in detail in tables 59 to 70, it must be borne in mind that the conditions are altogether different from those with Squad A. Squad A had, to be sure, a reduced diet, but Squad B was given what may be termed a greatly reduced diet, that is, a diet certainly less than half of their normal diet maintenance requirements. No

TABLE 72.—*Nitrogen balance and energy available to body during period of reduced diet—Squad B.*

[Averages per day, January 7 to 28, 1918.]

| Subject. | Nitrogen in— | | | Loss of nitrogen. | Energy in— | | | Net energy. |
|---|---|---|---|---|---|---|---|---|
| | Food. | Feces. | Urine. | | Food. | Feces. | Urine. | |
| | *gm.* | *gm.* | *gm.* | *gm.* | *cals.* | *cals.* | *cals.* | *cals.* |
| Fis..... | 8.28 | 1.40 | 9.66 | 2.80 | 1,592 | 145 | 77 | 1,370 |
| Har.... | 8.03 | .74 | 10.43 | 3.14 | 1,538 | 96 | 83 | 1,358 |
| How.... | 8.22 | .84 | 10.87 | 3.48 | 1,579 | 110 | 87 | 1,382 |
| Ham... | 7.54 | .53 | 11.52 | 4.50 | 1,432 | 79 | 92 | 1,261 |
| Kim.... | 8.44 | .88 | 9.18 | 1.63 | 1,624 | 120 | 73 | 1,430 |
| Lon.... | 8.18 | .63 | 9.51 | 1.96 | 1,576 | 91 | 76 | 1,409 |
| Sch..... | 8.23 | .88 | 9.75 | 2.40 | 1,586 | 117 | 78 | 1,391 |
| Liv..... | 8.30 | .68 | 11.82 | 4.17 | 1,588 | 108 | 94 | 1,386 |
| Sne..... | 8.37 | .99 | 10.36 | 2.95 | 1,611 | 116 | 83 | 1,412 |
| Tho.... | 8.24 | 1.20 | 10.74 | 3.70 | 1,587 | 138 | 86 | 1,363 |
| Van.... | 8.11 | .99 | 9.96 | 2.83 | 1,570 | 126 | 80 | 1,365 |
| Wil..... | 8.39 | .92 | 11.01 | 3.67 | 1,593 | 132 | 88 | 1,372 |
| Av... | 8.19 | ....... | ....... | 3.10 | ........ | ....... | ....... | 1,375 |

complicating circumstances such as uncontrolled days enter into their values. The total nitrogen in the food intake is extraordinarily low, averaging 8.19 grams, and the average net energy 1,375 calories. With but few exceptions, the daily values for the nitrogen balance for the individual subjects are minus. (See tables 59 to 70.) Losses of 9 or 10 grams of nitrogen are occasionally noted and not infrequently 5, 6, and 7 grams. In general, the losses are much more pronounced than they were in any stage of the experiment with Squad A. The average daily loss per man as given in table 72 is 3.10 grams of nitrogen. This indicates the severity of the curtailment of the diet, for it is greater than the average loss with Squad A which was but 2.30 grams per day.

If one considers the individual balance tables for Squad A with a general view to the appearance of plus signs and the magnitude of minus values in the nitrogen balance and compares these figures with

the energy balance showing the average net energy available to the body in the several periods of the experiment, it will be seen that there is a very close correlation between nitrogen loss and low net energy. In general, when the net energy is low, the minus figures appear in large proportion and the loss in nitrogen increases.

With Squad B the reduction in diet was so great, and the total energy available to the body was so small, that the period was not sufficiently long to bring the body-weight to a level and thus permit the drawing of definite quantitative comparisons between the total caloric intake and the average nitrogen loss. It is clear, however, that the large losses found with these subjects, taken into consideration with the small caloric intake, are fully in accord with the general picture shown for Squad A.

There seems to be, therefore, some very definite relationship between the total energy intake and the nitrogen loss, a relationship most strikingly shown with Squad A. Indeed, it is not impossible to conceive that were one to adjust the diet so as to obtain nitrogen equilibrium one would also have energy equilibrium.[1] This, of course, was by no means clearly and definitely proved, but is strongly suggested by the figures in the individual tables for the several men.

Since the total caloric intake on the average bears a very close relationship to the body-weight curve, as shown in figures 57 to 68, we may reason that if the diet had been adjusted to secure nitrogen equilibrium without regard to the calories, the body-weight would have likewise reached equilibrium. In other words, the loss of nitrogen is directly associated with a loss of body-material, not simply nitrogenous material but that which results in an ultimate material lowering of the body-weight.

That it would be possible for a group of men to lose from 130 to 250 grams of nitrogen over a period of this time and not show profound disturbance would, a decade ago, hardly have been believed. Experience with a man who fasted 31 days in the Nutrition Laboratory and during this time lost 277 grams of nitrogen has, however, given us a different impression of the significance of the so-called nitrogen "balance" or the loss of nitrogen from the body. It is hardly probable that any great amount of organized body-tissue is disintegrated in this loss of nitrogen. We regret that experimental exigencies were such that we could not determine the blood nitrogen and its apportionment. This must remain one of the problems to be solved subsequently. It seems very clear, however, that when the calories are deficient and the body must draw upon its store for caloric material, there is simultaneously a considerable loss of nitrogen. The potential energy of the protein corresponding to the nitrogen thus lost can not account for any appreciable percentage of the energy lost from the

[1] Klemperer, Zeitschr. f. klin Med., 1889, 16, p. 597.

body or furnished by the body to make up the deficiency in caloric intake. But the nitrogen thus lost is undoubtedly an appreciable percentage of the total body-nitrogen. A subsequent discussion of the energy transformations of these men shows that a very great lowering of energy transformation takes place simultaneously with the loss in body-weight and the loss of this excess nitrogen. Our suggestion is that the nitrogen thus lost comes from the fluid bathing the cells, and is in some form which stimulates them to their normal level of activity. We have, therefore, loss of body-nitrogen closely correlated with general loss in body-weight and with reduced intake of energy.

It is to be remembered that with these men the loss in body-weight resulted in general from a deficiency in the intake of food. In certain cases this deficiency of intake was undoubtedly supplemented in its effect upon the body-weight loss by excessive physical exercise. An interesting problem immediately suggests itself as to what would have been the influence of the nitrogen loss had the caloric intake remained constant and had the body-weight loss been produced by excessive physical exercise alone, a problem of far-reaching physiological importance and possibly of considerable athletic significance.

## CORRECTION OF PRELIMINARY STATEMENTS.

It is necessary at this time to point out an error made recently by us in a preliminary report of this research before the National Academy of Sciences in Washington, D. C. In this report it was stated that "the nitrogen output per day at the maintenance diet of 2,300 net calories was about 9 grams. A control group of 12 men, living substantially the same life and eating in the same dining-room, but with unrestricted diet, showed a nitrogen output of 16 to 17 grams per day."[1] Three serious errors appeared in this statement:

(1) The caloric intake at the lowest weight level was not 2,300 calories, but 1,950 calories.

(2) An examination of the nitrogen balance tables (tables 46 to 58) shows clearly that the value of 9 grams for the nitrogen excretion at the lowest level of weight maintenance (December 3 to February 3) is too small, and that it should be 10.5 grams (see table 73). While one subject, *Tom*, excreted only 7.7 grams, another subject, *Can*, excreted invariably over 11 grams (see table 35) and averaged 12.0 grams.

(3) The statement that a control group of 12 men excreted from 16 to 17 grams is erroneous in that these figures represent not the nitrogen excretion but the nitrogen of the food. By reference to table 32 it can be seen that the nitrogen intake of a control group of 12 men ranged in 5 days from 17.06 to 20.80 grams, with an average of 18.46 grams. As has already been stated, our information regarding the normal excre-

[1] Benedict and Roth, Proc. Nat. Acad. Sci., 1918, 4, p. 151.

tion of nitrogen of our subjects is unfortunately scanty, but table 45 shows that the nitrogen excretion of a group of men on February 11 to 16, 1918, with normal unrestricted diet, averaged 13.97 grams.

TABLE 73.—*Average daily nitrogen excretion at low weight-level—Squad A.*

| Subject. | Nitrogen excretion per 24 hrs. | Subject. | Nitrogen excretion per 24 hrs. |
|---|---|---|---|
| | *gm.* | | *gm.* |
| Bro...... | 10.2 | Moy..... | 11.4 |
| Can...... | 12.0 | Pea...... | 11.1 |
| Kon..... | 11.6 | Pec...... | 10.8 |
| Gar...... | 10.2 | Tom..... | 7.7 |
| Gul...... | 9.2 | Vea...... | 10.1 |
| Mon..... | 11.5 | | |
| | | Av... | 10.5 |

NITROGEN OUTPUT OF MEDICAL STUDENTS.

Subsidiary evidence regarding the normal nitrogen excretion is supplied by the average excretion of nitrogen found with the class in physiology in the Harvard Medical School for a number of years past. In the absence of Professor Walter B. Cannon, we must rely upon lecture notes kindly placed at our disposal by Dr. T. M. Carpenter. From analyses of the urinary output of these groups of 40 or more medical students, collected for three successive days, in the years 1909 to 1915, inclusive, the following average values per man per day were obtained: 13.8, 12.0, 12.7, 13.3, 12.7, 12.2, and 12.2 grams of nitrogen excreted. These values are distinctly lower than one would expect when it is considered that the American is commonly believed to live upon the so-called Voit protein standard. The low values found by us with the Y. M. C. A. College students might perhaps be ascribed to the strong tendency at the present time to conserve on meat products, and incidentally on protein foods, the physiological thought in this case being undoubtedly profoundly influenced by the experiments of Professor Chittenden. On the other hand, the fact that the students at the Harvard Medical School have shown these low values since 1909 indicates that the earlier estimates of the American excretion of nitrogen must have been high. The values we find, therefore, are not surprisingly low, and this subsidiary evidence obtained with the medical students confirms our belief that the normal nitrogen excretion of the Y. M. C. A. College undergraduate is not far from 13 to 14 grams. The excessive physical exercise and probably larger amounts of food eaten by the students of the Springfield college, as compared with the students of the Harvard Medical School, would normally account for the slightly higher nitrogen output and protein level at which they were living.

NITROGEN OUTPUT OF SQUAD A AT LOW WEIGHT-LEVEL.

The average nitrogen excretion of Squad A from December 3 to the end of the experiment was 10.5 grams. (See table 73.) This probably represents on the whole the most constant period of lower weight during the experiment, although the second part of this period is complicated by the abnormal rises in weight incident to the Christmas vacation. We may take this nitrogen value, therefore, as an approximate indication of the level of nitrogen upon which these men were capable of living with their lowered intake.

A comparison of the nitrogen excretions in the urine at these different weight-levels is of great significance as indicating the possibility of a material reduction of protein in the diet, protein being one of the most costly food constituents. After the extensive experience of Professor Chittenden, and more particularly the recent compulsory experience of the Central Powers, any real danger from a reduction of protein in the intake seems to be lacking. It was emphasized at the outset that we did not intend to complicate our problem by control of the protein intake. We were not advocating either a high or a low protein diet or a vegetarian or mixed diet. We were confessedly somewhat surprised at the conclusion of the research to find that the nitrogen excretion, especially at the lower weight-level, and with a material reduction in the caloric intake still remained so high, for we had expected it to be somewhat lower. The fact that this did not come to our attention until some time after the experiment ceased shows the complete objectivity of our method of weight reduction and food control. The criterion as to food allotment was, in every instance, the actual weight of the subject. Since the exact knowledge of the intake of nitrogen and energy depends upon chemical analysis and determination of the heat of combustion, the actual ingestion of energy and nitrogen per day could only be computed several weeks later. This in part accounts for the noticeable variations in the intake of energy and nitrogen frequently appearing in the tables.

We have no reason to believe that a somewhat lower protein level might not have readily been obtained without a correspondingly great increase in calories. This, however, remains a disputed point. The fact that nitrogen equilibrium, or at least an indication of nitrogen equilibrium in the frequent appearance of plus values at the lower weight-level, was obtained with the surprisingly low caloric intake of 1,950 calories is, we believe, a new feature. It has been supposed from earlier feeding experiments that no material reduction in the nitrogen excretion can be maintained without very considerably *increasing* rather than *decreasing* the calories. Professor Chittenden, without absolute caloric dietetic control, showed that his soldiers were able to subsist with a low nitrogen output with no great increment in calories. Indeed, his evidence strongly suggested lowered calories. This research fully confirms his inferences with regard to this point.

## CLINICAL EXAMINATION.

A preliminary medical examination of all but one of the men in Squad A was made by Dr. Walter H. Chapin, of Springfield, in October, 1917. The results of these examinations are given in the personal histories (see pp. 47 to 53). In addition, arrangements were made with Dr. H. W. Goodall, of Boston, to give the men a complete clinical examination every time they came to Boston for the biweekly experiments in the group respiration chamber. In these examinations of Dr. Goodall particular attention was given to blood pressure. The results of these determinations will be considered in another section. (See p. 370.) Dr. Goodall went over each man with characteristic care, which is particularly exemplified by his method in examining the subject of the long fast in the Nutrition Laboratory.[1] The members of Squad A were first seen by Dr. Goodall on October 13, 1917. His report, aside from blood-pressure observations, for each subject follows:

### DETAILS OF CLINICAL EXAMINATION.

*Bro.*—October 13, 1917, entirely negative, with exception of slightly enlarged tonsils and very small cervical glands. During the period of observation no change noted in general appearance, skin, mouth and contained organs, glands, reflexes, chest, or lungs, percussion outline of heart, or size of liver. Nothing remarkable noted in physical condition of abdominal organs. On February 2, 1918, right kidney felt for first time.

*Can.*—October 13, 1917, negative, with exception of slightly enlarged tonsils. Slight changes noted in percussion outline of heart area as follows: October 13, left border of cardiac dulness 11 cm. from median line, right, 2.5 cm.; October 27, left border, 11 cm., right border, 2 cm.; November 10, left border, 10 cm., right border 2 cm.; same on all following examinations. No change noted in abdominal organs except that on November 10, right kidney palpable for first time; felt at each subsequent examination.

*Fre.*—October 13, 1917, negative, except for very small cervical glands. Heart: Left border cardiac dulness 6.5 cm. from median line, right border, 1.5 cm. Seen only once.

*Gar.*—October 13, 1917, entirely negative, with exception of slightly enlarged tonsils. During period of observation no change noted in general appearance, skin, mouth and contained organs, glands, reflexes, chest, or lungs. Slight changes noted in percussion outline of heart as follows: October 13, left border of cardiac dulness 10 cm., right border 3 cm. from median line; October 27, left border 10 cm., right border 2 cm.; in all subsequent examinations left border, 9 cm., right border, 2 cm. No change noted in abdominal organs, except that on November 10 right kidney was just palpable and at all subsequent examinations.

*Gul.*—October 13, 1917, entirely negative, except for slightly enlarged tonsils and small cervical glands. During period of observation no change noted in general appearance, skin, mouth and contained organs, glands, reflexes, chest, and lungs. No change noted in percussion outline of heart or abdominal organs. Kidney not felt at any examination.

*Mon.*—October 13, 1917, entirely negative, with exception of slightly enlarged tonsils and small axillary glands. During period of observation

[1] Benedict, Carnegie Inst. Wash. Pub. No. 203, 1915, p. 53.

The general physical examination of all the men in Squad B was negative. Examinations were made on January 5, 13, 19, and 27, 1918, when all the men were seen. No changes were noted in the percussion of the heart area.

## GENERAL OBSERVATIONS.

In view of his extensive experience as a clinician and his practice in medical examinations, Dr. H. W. Goodall's observations and comments on these men as the research continued are significant. These are given in a letter written a few weeks after the close of the research, and reproduced here. In partial explanation of this letter it should be stated that Dr. Goodall said to one of us that he considered these men were in no condition to endure severe muscular exercise as, for example, trench fighting. It was in response to our request for an elaboration of this statement that he made the following comments:

"According to my notes the attention of the men was considerably fixed upon their low diet on the 10th of November. There was no evidence of any particular physical weakness at that time. On the 24th of November it seemed to me that they moved around with considerably less energy, and on the 8th of December they all complained of not feeling specially well. There was a distinct sense of fatigue on muscular exertion, they found it difficult to study, they were thinking of food all the time. After the Christmas holidays, however, they complained very little, and seemed much stronger and better. It was on the 8th of December that I told you I did not believe these men would be fit to do work in the trenches."

## ILLNESS.

With a group of 25 college students under observation for 3 to 4 months it would be expected that a certain number of minor illnesses, colds, slight infections, etc., would occur. These appeared in both Squads A and B and apparently as often in Squad B prior to dietetic restriction as in Squad A. In the personal histories, however, emphasis has been laid only upon those slight illnesses which were observed with Squad A. The extraordinary severity of the winter and the necessity for many of the men in Squad A to increase their clothing materially perhaps make it all the more surprising that a larger number of colds and minor illnesses did not occur. The question of constipation, which was present more or less as a result of the reduced and somewhat concentrated diet, was readily controlled in most cases by the use of bran and has been discussed in detail in the section on diets. The only serious trouble was with *Tom*, who stated that he believed the condition which made his operation for hemorrhoids necessary was the result of straining at stools during the reduced diet.

One of our first difficulties experienced with the two squads was the distinct tendency for the men to overeat on the free Sundays permitted once in two weeks. This resulted almost invariably, especially at the

beginning, in digestive disturbances which bordered on nausea and occasionally provoked diarrhea. This tendency to overeat, with consequent digestive disturbance, persisted more or less throughout the entire experiment in spite of repeated warnings.

In a number of instances there appeared to be clear evidence of so-called hunger pains. Certain of the men complained of a continuous gnawing sensation in the stomach, headaches, inability to study, etc. These minor disturbances were anticipated; in fact, the men were told at the beginning that discomfort might be experienced as a result of the restriction in diet. Only one subject found it necessary to withdraw on this account. *Fre*, three weeks after the beginning of the experiment, found himself discommoded by the feeling of hunger and the time demands of the experiment. He became very much disturbed, and, on the advice of the physician, withdrew from the squad. At first his physician suspected the discomfort might be due to a gastric ulcer, and with this possibility it appeared unwise to continue him on the squad. As a matter of fact, when full diet was resumed all his symptoms disappeared.

At least three of our subjects underwent ether narcosis for minor operations during the research. Thus *Bro* injured his foot in a football game and, as shown in his personal history (see p. 47), underwent ether narcosis for a resetting of the toe. He experienced no difficulty and made a rapid, uneventful recovery. *Kon* underwent ether narcosis for a throat and nose operation which involved the removal of adenoids and tonsils, trimming of turbinated bones, and straightening of the septum (see p. 48). *Tom*, in the Christmas vacation, was operated on for hemorrhoids under ether narcosis, but evidently returned to college too soon after the operation. Yet we have no reason to believe that the fact that he was on low diet in any way delayed his ultimate recovery. His post-dietetic history shows that he finished his college work in good condition and, in fact, was one of the best students in the institution.

The post-experimental history of practically all the men in both squads showed pronounced digestive disturbances following the return to normal diet. Special cautions were given to resume normal diet very slowly, but the men not only overate but, in certain instances, passed all reasonable bounds. The reports of the meals eaten by some of the men are so amazing as to seem of doubtful value and hence are not recorded here. Many suffered from abdominal pains and distress, not infrequently nausea, but usually all the men were in good condition within 2 or 3 days.

The most pronounced and puzzling development of abnormal nature throughout the entire test was that occurring with *Spe*. In the experiments in the group chamber apparatus on the morning of December 9 his rectal temperature at 6 a. m. was 97.6° F., and pulse rate 53. On

December 10 and 11 he reported that he felt very well. On December 12 he reported that he felt weak and that his throat was a little sore. His temperature at $5^h 45^m$ a. m. was 99.6° F. He was therefore excused from the respiration test and stayed in bed with a headache and a poor appetite. December 13 he reported himself as feeling better, with a temperature of 100.5° F. in the early morning. The temperature, taken at 2 p. m. by a local physician, was reported as 102° F. and the pulse rate as 120. At $6^h 30^m$ p. m. the temperature was 102.5° F. and the pulse-rate was 102. The physician and two others suspected typhoid fever and advised him to return home. On December 15, although he still had a high fever, he went to his home at Andover, Massachusetts, and the case was pronounced typhoid fever by his local physician. The subsequent course of the disease is best recorded by the charts of the temperature, pulse, and respiration (figure 87), and by the reports kindly furnished us by the subject's physician, Dr. W. D. Walker, of Andover.

The treatment given *Spe*, as outlined by Dr. Walker, is as follows:

"Warm bath every day; cold sponge for temperature; mouth irrigated with Dobell's solution every 2 hours; swabs of Tr. Myrrh frequently; gargle and spray before and after feedings; drops in the eyes three times a day."

The physician adds that his patient had 24 days of temperature, a very sore mouth for two weeks and a cough. Through Dr. Walker's kindness we are permitted to quote from his letters further as follows:

"Wesley G. Spencer came home from Springfield with a diagnosis of typhoid fever. At the end of nine days he had a crop of what I supposed were rose spots, but their subsequent behaviour leads me to conclude that I was wrong. They were at first rosy red, much larger than the ordinary rose spot and speedily became vesicles. They were all over the body, but more especially on the penis and scrotum, where they caused considerable irritation. All this time the patient's mouth was in a most deplorable state in spite of constant care. A bronchitis was present. The temperature chart you have. There were no abdominal symptoms. A slight trace of albumin was present in the early part of the fever. Widal reactions taken at weekly intervals negative. Urine and stools negative for typhoid bacilli. I conclude that he did not have typhoid, but I cannot make a diagnosis."

Subsequent correspondence with Dr. Walker, with special reference to the character of the vesicles, is as follows:

"The eruption in his case came on the ninth or tenth day, first on the abdomen and arms. It was at first very much like large rose spots, but these in a day or two became vesicular. There was no bleeding. I should say there was no ulceration, except on the scrotum and glans penis, where the eruption was abundant and marked. There was some pigmentation after the vesicles dried up and the spots were still visible after several weeks. The mouth first became involved about the sixth or seventh day of the disease. I am not quite clear as to the progress of this condition, but the whole inner surface of the cheeks and tongue was involved and covered with a dirty greyish membranous coating which finally peeled off after at least a week and possibly longer. There was considerable bleeding from the areas

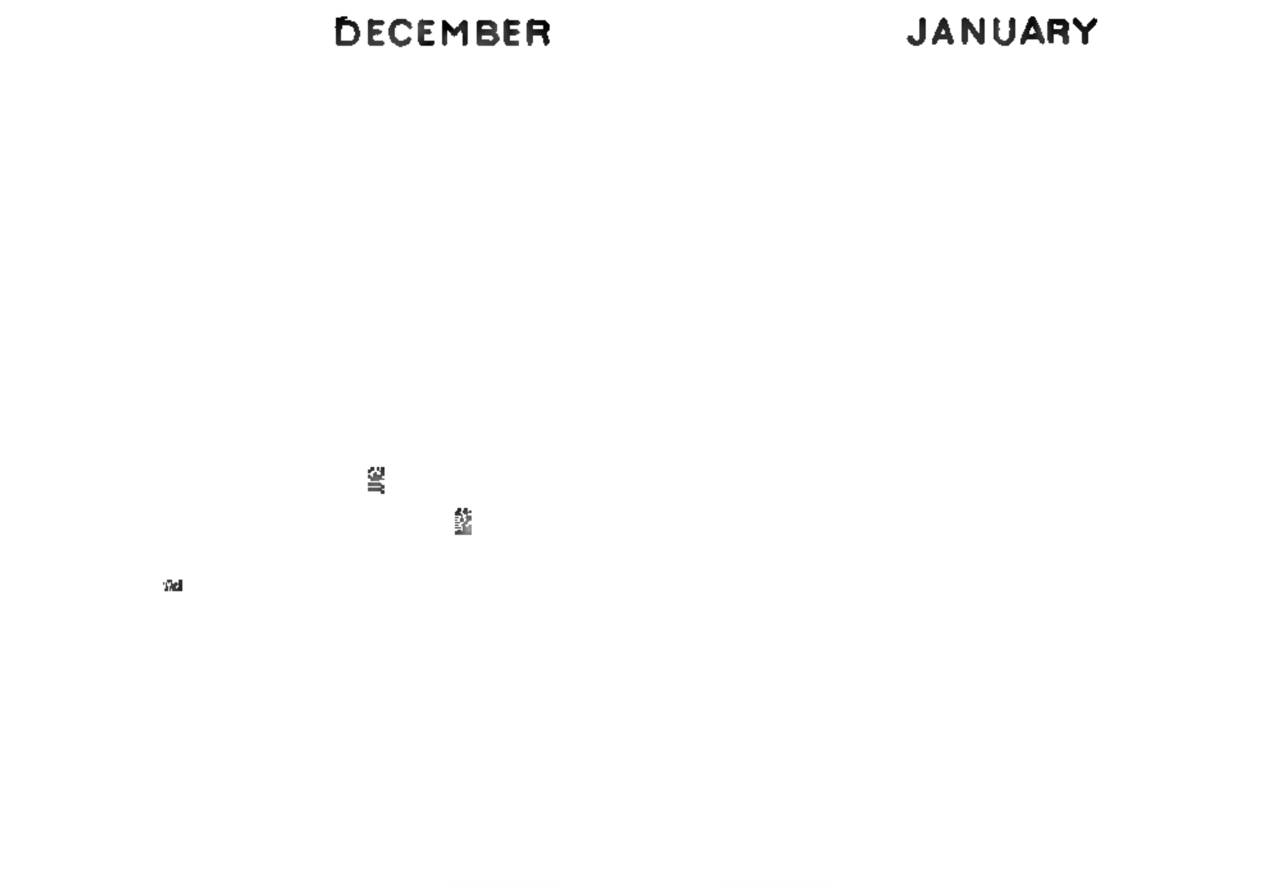


Fig. 87.—Temperature, pulse, and respiration charts of Wesley G. Spencer (*Spe*) during suspected infection of typhoid fever, December 12, 1917—January 21, 1918.

## BLOOD EXAMINATION.

Although the morphological changes in blood observed for the fasting man previously studied in this Laboratory[1] were relatively slight, it seemed desirable to secure certain evidence as to the blood with the subjects of the low-diet research, so as to contribute in every way possible to the general picture of the influence of a reduced diet. Accordingly, through the kind offices of Dr. George R. Minot, the services were enlisted of Miss Anna L. Gibson and Miss Myra B. Conover, the expert technicians of the Collis P. Huntington Memorial Hospital. Blood counts were made on both squads when they came to Boston for the biweekly experiments.

Additional information regarding the possible effect of the diet upon the blood is given by the fact that at no period throughout the test did the subjects appear to the examining physician as at all anemic. He saw them, however, only under artificial light. Dr. J. H. Kellogg, of the Battle Creek Sanitarium, when at the Laboratory on the last day of the research, thought the men appeared anemic. Professor G. B. Affleck, of the International Y. M. C. A. College, who was one of the coaches and instructors and saw the men in gymnasium suits and under the best daylight conditions, also thought the men looked anemic.

As was noted in the personal histories (see p. 49), one of the subjects, *Gul*, donated blood for transfusions at the Springfield Hospital, the amounts being on December 23, 100 c.c.; on December 29, 50 c.c.; on January 6, 90 c.c.; and on January 17, 50 c.c., making a total amount of 290 c.c.

The data obtained from the blood examinations in this research are given in tables 74 and 75. These values may be compared with the statement of Loewy and Zuntz, who report "as a good sign" that in their study on themselves the determinations made by the Plesch hemoglobinometer showed for both of them 110 per cent hemoglobin.

For the interpretation of the large number of blood counts made by Miss Gibson and Miss Conover, we are very much indebted to Dr. Minot, who has been good enough to contribute the appended report:

BOSTON, MASS., *June 18, 1918.*

The data on the blood examinations made by Miss Gibson and Miss Conover, both expert technicians and nurses of the Collis P. Huntington Memorial Hospital, show in general, I think, that both Squads A and B developed during the course of the experiment a definite, though slight to mild, secondary anemia. In general, it is evident that both the hemoglobin and red count are reduced, and the color index tends to be lower than normal. (Eighty-five per cent or above for the hemoglobin is normal with the Sahli instrument used.) These findings are very slight in some instances, and quite marked in others, and more evident with Squad A than Squad B. In certain instances it may be noted that instead of a progressively falling red count, there occurs a slightly increased count following a previously lower

[1] Benedict, Carnegie Inst. Wash. Pub. No. 203, 1915, p. 148.

count. This may be dependent upon a temporary concentration of the blood, or dependent perhaps upon an actual increase of cells which are relatively poor in hemoglobin, as told by their histological character and the fact that the hemoglobin did not significantly rise with the increased count. The relatively slight histological abnormalities noted about the red cells, the achromia, anisocytosis, occasionally polychromatophilia, are those associated with slight or mild secondary anemia.

The white counts, in general, average 9,500, but little higher than normal (normal average, 7,300). With Squad B, who had not been so long on reduced diet, the white counts showed no alteration. The evidence is therefore negative so far as the white counts alone are concerned.

The white cells are evidently of the normal types, but their normal proportion is disturbed. This is evidenced by the fact that the average per cent (36) and the average absolute number (3,400) of the lymphocytes are unusually high for individuals in this vicinity, the average normal lymphocyte count being 22 per cent (though the upper normal limit may be 40 per cent) and the average normal absolute count being 1,724.[1] In Squad B, in certainly 8 out of 12 cases, the lymphocytes definitely increased, both relatively and absolutely, under observation, while, though variations occur in Squad A, the average lymphocyte count is certainly well above the normal average. This increase is perhaps at the expense of polynuclear neutrophile production, for the polynuclear per cent, both squads, averages 56 per cent, which is slightly lower than the normal average, 64 per cent. However, the average absolute number of polynuclears is not so significantly altered from their normal average (4,895) as are the lymphocytes. This increase of lymphocytes is not an unusual finding in chronic secondary anemia.

The other white cells show no definite significant alteration, though in some instances the eosinophiles are very slightly more numerous than normal. Satisfactory data concerning the blood platelets, the third formed element of the blood, originating from myelogenous tissue, are unfortunately lacking. One usually finds them increased in secondary anemia, although when associated with decreased blood formation, they may become decreased.

The secondary anemia present in these cases may be dependent, perhaps, in some manner upon a decreased rate of blood formation, possibly similar to that which occurs in myxedema.

It is interesting to speculate as to what might happen to the blood of these individuals if they were kept on this same diet for a considerably longer period of time. I am inclined to believe that, under such circumstances, a greater degree of secondary anemia than the most marked case shows would probably not occur, or that it would be but very slightly greater. In other words, it seems to me that their blood would stay at a new level, one which we would interpret as a mild secondary anemia. However, I think that, if for any considerable time the blood remained at this new level, it would probably be quite difficult, perhaps impossible, for it to return to its previous normal level, and that if it did return to normal, it would probably do so very slowly. This is because, from clinical experience, the blood of cases of chronic mild secondary anemia, dependent upon various minor causes, not infrequently improves only slightly following prolonged appropriate treatment. It would seem in some such instances as if some "trap had been sprung" which could not be entirely repaired to let the completely normal hemopoetic function take place again. This may be well seen in certain rather marked and unusual cases of anemia dependent upon chronic benzol poisoning— a drug which causes an aplastic type of anemia.

GEORGE R. MINOT, M. D.

[1] S. R. Miller, Johns Hopkins Hospital Bulletin, 1914, 25, p. 317.

TABLE 74.—*Results of blood examinations during period of reduced diet—Squad A.*

| Subject and date. | Time. | Hemoglobin. (Sahli). | Total erythrocytes. | Total leucocytes. | Differential counts. Polymorphonuclear neutrophiles. Total. | Polymorphonuclear neutrophiles. Per cent. | Lymphocytes. Total. | Lymphocytes. Per cent. | Mononuclears. Total. | Mononuclears. Per cent. | Eosinophiles. Total. | Eosinophiles. Per cent. | Remarks on erythrocytes. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BRO. | *p. m.* | *p. ct.* | *millions.* | | | | | | | | | | |
| Dec. 19, 1917... | 8.20 | 80 | 4.568 | 8,400 | 5,124 | 61 | 2,520 | 30 | 756 | 9 | ....... | ..... | Slight achromia and anisocytosis. |
| Jan. 12, 1918... | 8.35 | 80 | 3.420 | 10,400 | 6,240 | 60 | 3,328 | 32 | 728 | 7 | 104 | 1 | Do. |
| Jan. 26, 1918... | 9.20 | 76 | 3.880 | 12,000 | 6,480 | 54 | 5,040 | 42 | 480 | 4 | ....... | ..... | Considerable achromia and slight anisocytosis. |
| Feb. 918... | 7.40 | 78 | 3.840 | 8,000 | 4,160 | 52 | 3,200 | 40 | 560 | 7 | 80 | 1 | Slight achromia and anisocytosis. |
| CAN. | | | | | | | | | | | | | |
| Dec. 19, 1917... | 7.20 | 80 | 3.856 | 14,000 | 9,800 | 70 | 2,940 | 21 | 980 | 7 | 280 | 2 | Slight achromia and anisocytosis. |
| Jan. 12, 1918[1].. | 9.25 | 72 | 3.200 | 12,000 | 7,560 | 63 | 3,600 | 30 | 720 | 6 | ....... | ..... | Do. |
| Jan. 26, 1918[2].. | 7.45 | 78 | 3.688 | 7,000 | 3,780 | 54 | 2,380 | 34 | 630 | 9 | 140 | 2 | Marked achromia and slight anisocytosis. |
| Feb. 2, 1918... | 7.20 | 72 | 5.080 | 12,800 | 7,424 | 58 | 4,608 | 36 | 768 | 6 | ....... | ..... | Slight achromia. |
| KON. | | | | | | | | | | | | | |
| Dec. 19, 1917... | 8.30 | 76 | 5.368 | 6,000 | 3,300 | 55 | 2,400 | 40 | 180 | 3 | 120 | 2 | Considerable achromia and anisocytosis. |
| Jan. 12, 1918... | 7.15 | 74 | 4.280 | 9,000 | 5,850 | 65 | 2,610 | 29 | 540 | 6 | ....... | ..... | Do. |
| Jan. 26, 1918... | 8.15 | 78 | 4.480 | 9,200 | 5,980 | 65 | 2,760 | 30 | 368 | 4 | 92 | 1 | Slight achromia. |
| Feb. 2, 1918... | 8.00 | 78 | 4.832 | 9,600 | 6,144 | 64 | 2,688 | 28 | 576 | 6 | 192 | 2 | Do. |
| GAR. | | | | | | | | | | | | | |
| Dec. 19, 1917... | 8.50 | 80 | 5.976 | 16,000 | 7,200 | 45 | 6,560 | 41 | 1,280 | 8 | 960 | 6 | Slight achromia, polychromatophilia and anisocytosis. |
| Jan. 12, 1918... | 8.35 | 70 | 4.621 | 9,600 | 4,128 | 43 | 4,512 | 47 | 576 | 6 | 384 | 4 | Slight achromia and anisocytosis. |
| Jan. 26, 1918... | 8.55 | 73 | 4.328 | 10,000 | 5,400 | 54 | 4,000 | 40 | 500 | 5 | 100 | 1 | Do. |
| Feb. 2, 1918... | 8.20 | 70 | 4.132 | 7,200 | 4,320 | 60 | 2,592 | 36 | 288 | 4 | ....... | ..... | Do. |
| GUL. | | | | | | | | | | | | | |
| Dec. 19, 1917[3].. | 7.20 | 74 | 5.728 | 10,800 | 5,508 | 51 | 3,780 | 35 | 1,080 | 10 | 324 | 3 | Slight anisocytosis. |
| Jan. 12, 1918... | 9.05 | 76 | 4.480 | 10,800 | 5,940 | 55 | 3,888 | 36 | 432 | 4 | 540 | 5 | Considerable achromia. |
| Jan. 26, 1918... | 9.05 | 78 | 4.288 | 8,600 | 4,902 | 57 | 2,580 | 30 | 688 | 8 | 430 | 5 | Slight anisocytosis. |
| Feb. 2, 1918... | 8.20 | 75 | 4.160 | 8,000 | 3,840 | 48 | 3,680 | 46 | 480 | 6 | ....... | ..... | Slight achromia and anisocytosis. |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MON.** | | | | | | | | | | | | | |
| Dec. 19, 1917... | 9.10 | 75 | 4.240 | 9,000 | 4,950 | 55 | 3,150 | 35 | 630 | 7 | 270 | 3 | Considerable achromia and anisocytosis. |
| Jan. 12, 1918... | 8.05 | 70 | 4.416 | 11,200 | 4,928 | 44 | 5,488 | 49 | 448 | 4 | 336 | 3 | Do. |
| Jan. 26, 1918... | 8.35 | 80 | 4.536 | 8,800 | 4,752 | 54 | 3,520 | 40 | 528 | 6 | ........ | ..... | Normal. |
| Feb. 2, 1918... | 7.40 | 76 | 4.132 | 8,000 | 4,960 | 62 | 2,800 | 35 | 240 | 3 | ........ | ..... | Slight achromia. |
| MOY. | | | | | | | | | | | | | |
| Dec. 19, 1917... | 8.10 | 80 | 5.040 | 12,800 | 6,912 | 54 | 4,224 | 33 | 1,280 | 10 | 384 | 3 | Considerable achromia and anisocytosis. |
| Jan. 12, 1918... | 7.40 | 80 | 4.924 | 8,800 | 5,544 | 63 | 2,640 | 30 | 352 | 4 | 264 | 3 | Normal. |
| Jan. 26, 1918... | 7.25 | 81 | 4.400 | 8,200 | 4,428 | 54 | 3,116 | 38 | 328 | 4 | 328 | 4 | Do. |
| Feb. 2, 1918... | 7.00 | 80 | 4.960 | 12,000 | 6,240 | 52 | 4,560 | 38 | 720 | 6 | 480 | 4 | Do. |
| PEA. | | | | | | | | | | | | | |
| Dec. 19, 1917... | 9.00 | 72 | 4.880 | 10,600 | 5,300 | 50 | 4,134 | 39 | 742 | 7 | 424 | 4 | Considerable achromia and anisocytosis. |
| Jan. 12, 1918... | 8.05 | 72 | 3.840 | 9,600 | 4,800 | 50 | 3,840 | 40 | 576 | 6 | 384 | 4 | Do. |
| Jan. 26, 1918... | 7.25 | 78 | 4.280 | 8,000 | 4,000 | 50 | 3,280 | 41 | 480 | 6 | 240 | 3 | Slight achromia and anisocytosis. |
| Feb. 2, 1918... | 8.00 | 75 | 3.680 | 8,000 | 4,480 | 56 | 2,880 | 36 | 320 | 4 | 320 | 4 | Do. |
| PEC. | | | | | | | | | | | | | |
| Dec. 19, 1917... | 7.50 | 88 | 6.840 | 9,000 | 4,770 | 53 | 3,150 | 35 | 900 | 10 | 180 | 2 | Slight anisocytosis. |
| Jan. 12, 1918... | 7.15 | 86 | 4.456 | 5,400 | 2,592 | 48 | 2,484 | 46 | 324 | 6 | ........ | ..... | Normal. |
| Jan. 26, 1918... | 9.40 | 78 | 4.664 | 8,000 | 4,000 | 50 | 3,600 | 45 | 400 | 5 | ........ | ..... | Do. |
| Feb. 2, 1918... | 7.20 | 76 | 4.000 | 8,200 | 5,576 | 68 | 2,132 | 26 | 410 | 5 | 82 | 1 | Slight achromia. |
| TOM. | | | | | | | | | | | | | |
| Dec. 19, 1917... | 8.00 | 70 | 4.400 | 8,000 | 4,400 | 55 | 2,560 | 32 | 560 | 7 | 480 | 6 | Considerable achromia and anisocytosis. |
| Jan. 12, 1918... | 9.05 | 66 | 5.120 | 8,800 | 4,840 | 55 | 3,432 | 39 | 264 | 3 | 264 | 3 | Do. |
| Jan. 26, 1918... | 9.36 | 78 | 5.160 | 12,800 | 7,168 | 56 | 4,608 | 36 | 768 | 6 | 256 | 2 | Normal. |
| Feb. 2, 1918... | 7.00 | 80 | 4.508 | 12,800 | 7,488 | 59 | 4,512 | 35 | 544 | 4 | 256 | 2 | Do. |
| VEA. | | | | | | | | | | | | | |
| Dec. 19, 1917... | 8.40 | 92 | 4.408 | 7,000 | 3,920 | 56 | 2,170 | 31 | 420 | 6 | 490 | 7 | Slight achromia. |
| Jan. 12, 1918... | 7.40 | 60 | 4.496 | 6,600 | 3,300 | 50 | 2,640 | 40 | 462 | 7 | 198 | 3 | Slight achromia and anisocytosis. |
| Jan. 26, 1918... | 8.15 | 64 | 4.608 | 7,200 | 4,104 | 57 | 2,376 | 33 | 576 | 8 | 144 | 2 | Considerable achromia and anisocytosis. |
| Feb. 2, 1918... | 8.35 | 70 | 4.000 | 8,000 | 4,240 | 53 | 3,040 | 38 | 480 | 6 | 240 | 3 | Considerable achromia and slight anisocytosis. |
| Average.. | ...... | 76 | 4.504 | 9,460 | 5,245 | 55 | 3,409 | 36 | 576 | 6 | 222 | 2.3 | |

[1] Mast cells, 120 or 1 per cent. [2] Mast cells, 70 or 1 per cent. [3] Mast cells, 108 or 1 per cent.

TABLE 75.—*Results of blood examinations—Squad B.*

| Subject and date. | Time. | Hemoglobin. (Sahli). | Total erythrocytes. | Total leucocytes. | Differential counts. Polymorphonuclear neutrophiles. Total. | Polymorphonuclear neutrophiles. Per cent. | Lymphocytes. Total. | Lymphocytes. Per cent. | Mononuclears. Total. | Mononuclears. Per cent. | Eosinophiles. Total. | Eosinophiles. Per cent. | Remarks on erythrocytes. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FIS. | *p. m.* | *p. ct.* | *millions.* | | | | | | | | | | |
| Jan. 5, 1918[1] | 7.45 | 86 | 5.754 | 8,000 | 4,000 | 50 | 2,720 | 34 | 800 | 10 | 320 | 4 | Normal. |
| Jan. 13, 1918[2] | 6.50 | 85 | 4.842 | 12,800 | 8,192 | 64 | 3,968 | 31 | 384 | 3 | 128 | 1 | Do. |
| Jan. 19, 1918 | 7.40 | 85 | 5.216 | 10,400 | 5,200 | 50 | 4,680 | 45 | 520 | 5 | ........ | ..... | Do. |
| Jan. 27, 1918 | 7.15 | 87 | 5.336 | 5,600 | 2,800 | 50 | 2,240 | 40 | 504 | 9 | 56 | 1 | Do. |
| HAR. | | | | | | | | | | | | | |
| Jan. 5, 1918[3] | 8.00 | 80 | 4.200 | 9,600 | 5,856 | 61 | 2,640 | 27.5 | 960 | 10 | 48 | 0.5 | Normal. |
| Jan. 13, 1918 | 7.40 | 80 | 4.401 | 9,600 | 4,896 | 51 | 3,840 | 40 | 192 | 2 | 672 | 7 | Do. |
| Jan. 19, 1918 | 7.40 | 78 | 3.520 | 9,200 | 4,876 | 53 | 3,680 | 40 | 276 | 3 | 368 | 4 | Slight achromia. |
| Jan. 27, 1918 | 7.55 | 82 | 3.360 | 10,000 | 6,000 | 60 | 3,500 | 35 | 400 | 4 | 100 | 1 | Do. |
| HOW. | | | | | | | | | | | | | |
| Jan. 5, 1918 | 8.40 | 95 | 5.160 | 8,000 | 4,800 | 60 | 2,400 | 30 | 720 | 9 | 80 | 1 | Normal. |
| Jan. 13, 1918 | 7.40 | 85 | 4.120 | 6,000 | 3,840 | 64 | 1,860 | 31 | 240 | 4 | 60 | 1 | Slight anisocytosis. |
| Jan. 19, 1918 | 8.20 | 72 | 4.288 | 8,000 | 4,480 | 56 | 3,200 | 40 | 320 | 4 | ........ | ..... | Slight anisocytosis and achromia. |
| Jan. 27, 1918 | 8.40 | 85 | 4.320 | 8,800 | 4,224 | 48 | 3,960 | 45 | 616 | 7 | ........ | ..... | Normal. |
| HAM. | | | | | | | | | | | | | |
| Jan. 5, 1918 | 8.24 | 90 | 4.576 | 8,000 | 4,960 | 62 | 2,240 | 28 | 560 | 7 | 240 | 3 | Normal. |
| Jan. 13, 1918 | 6.50 | 90 | 4.680 | 8,200 | 5,084 | 62 | 2,460 | 30 | 492 | 6 | 164 | 2 | Do. |
| Jan. 19, 1918 | 6.50 | 78 | 4.512 | 8,800 | 4,752 | 54 | 3,520 | 40 | 264 | 3 | 264 | 3 | Slight achmroia. |
| Jan. 27, 1918 | 7.35 | 87 | 5.496 | 7,600 | 3,420 | 45 | 3,268 | 43 | 608 | 8 | 304 | 4 | Normal. |
| KIM. | | | | | | | | | | | | | |
| Jan 5, 1918 | 9.15 | 82 | 5.584 | 8,000 | 4,400 | 55 | 3,200 | 40 | 320 | 4 | 80 | 1 | Normal. |
| Jan. 13, 1918 | 8.40 | 84 | 4.672 | 8,800 | 4,136 | 47 | 3,784 | 43 | 704 | 8 | 176 | 2 | Do. |
| Jan. 19, 1918 | 8.35 | 80 | 4.032 | 12,800 | 6,400 | 50 | 5,632 | 44 | 768 | 6 | ........ | ..... | Do. |
| Jan. 27, 1918 | 9.20 | 75 | 4.192 | 6,000 | 3,000 | 50 | 2,700 | 45 | 240 | 4 | 60 | 1 | Considerable achromia and anisocytosis. |
| LOW. | | | | | | | | | | | | | |
| Jan. 13, 1918 | 8.05 | 80 | 4.000 | 10,600 | 7,844 | 74 | 2,120 | 20 | 424 | 4 | 212 | 2 | Slight achromia. |
| Jan. 19, 1918 | 6.50 | 84 | 3.200 | 8,000 | 5,120 | 64 | 2,400 | 30 | 320 | 4 | 160 | 2 | Do. |
| Jan. [illegible], 1918 | 8.20 | 72 | 5.440 | 8,000 | 4,000 | 50 | 3,600 | 45 | 400 | 5 | ........ | ..... | Slight achromia and anisocytosis. |

[1] Mast cells, 160 or 2 per cent.

[2] Mast cells, 128 or 1 per cent.

[3] Mast cells, 96 or 1 per cent.

[4] Mast cells, 100 or 1 per cent.

## BLOOD PRESSURE.

As the blood pressure is an important factor such determinations were made a part of the regular clinical examinations by Dr. H. W. Goodall when the men came to Boston for the experiments in the group respiration chamber. Standard technique was used, namely, the apparatus of the Taylor Instrument Company (Tycos) and the auscultatory method for both systolic and diastolic pressures. The particular instrument employed had the usual Bourdon gage. This was frequently compared with a mercury manometer to insure the accuracy of the blood-pressure records. The blood pressures recorded by Dr. Goodall were always taken with the subject in the sitting position and with the cuff on the left arm. These determinations were almost invariably made between 8 and 10 p. m., before the subjects entered the respiration chamber.

In the latter part of the research, a series of blood-pressure tests was made with a second instrument by one of us and by the skilled superintendent of the Huntington Memorial Hospital, Miss Anna L. Gibson. This instrument (a duplicate of the one used by Dr. Goodall) was likewise compared with a mercury manometer and its accuracy established. We have every confidence, therefore, in the two instruments used. Special emphasis is laid upon this fact, for the astounding changes in blood pressure render the technique liable to special scrutiny.

The second series of blood-pressure observations included a considerable number of blood pressures which were taken prior to the walking experiments. Successive observations were also recorded immediately after the cessation of walking. The subject was always in the standing position during these determinations, for the first few records, but additional records were made with the subject sitting, usually from 5 to 9 minutes after the walking had ceased. The series of observations after walking provided data for studying the influence of a moderate amount of physical work upon the blood pressure, both systolic and diastolic, and likewise upon the pulse pressure. Such records were deemed significant inasmuch as Cotton, Rapport, and Lewis[1] found a pronounced influence upon blood pressure with strenuous muscular work, even when continued only a short time.

Of special interest in this study is the course of the systolic and diastolic blood pressures and the pulse pressure as the investigation progressed. Unfortunately, we were not able to obtain records of blood pressure for Squad A prior to dietetic restriction. The need of such data is specially brought out in examining the blood pressures of the 12 members of Squad B. With Squad A the blood pressure was

[1] Cotton, Rapport, and Lewis, Heart, 1917, 6, p. 269.

measured first on October 13; the subjects had therefore been upon a reduced diet for 9 days prior to the first measurement.

## SYSTOLIC AND DIASTOLIC BLOOD PRESSURE, SQUAD A.

The records of the systolic and diastolic pressures and pulse pressure obtained between October 13 and February 2, inclusive, for Squad A are given in table 76. A glance at this table shows instantly that the blood pressure, both systolic and diastolic, greatly decreased as

TABLE 76.—*Blood-pressure measurements during period of reduced diet—Squad A.*

| Date and measurement.[1] | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pea. | Pec. | Spe. | Tom. | Vea. | Av. for squad. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 13, 1917:[2] | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* |
| Systolic | 115 | 118 | ..... | 115 | 118 | 115 | 120 | 100 | 115 | 116 | 120 | 118 | 115 |
| Diastolic | 90 | 100 | ..... | 75 | 75 | 80 | 70 | 70 | 85 | 88 | 80 | 80 | 81 |
| Pulse pressure | 25 | 18 | ..... | 40 | 43 | 35 | 50 | 30 | 30 | 28 | 40 | 38 | 34 |
| Oct. 27, 1917: | | | | | | | | | | | | | |
| Systolic | 104 | 100 | 140 | 100 | 100 | 100 | 102 | 90 | 105 | 104 | 95 | 100 | [3]103 |
| Diastolic | 80 | 70 | 90 | 78 | 70 | 82 | 68 | 65 | 75 | 70 | 75 | 60 | [3]74 |
| Pulse pressure | 24 | 30 | 50 | 22 | 30 | 18 | 34 | 25 | 30 | 34 | 20 | 40 | [3]30 |
| Nov. 10, 1917: | | | | | | | | | | | | | |
| Systolic | 105 | 90 | 110 | 90 | 90 | 90 | 110 | 90 | 85 | 105 | 90 | 95 | 96 |
| Diastolic | 80 | 70 | 90 | 75 | 65 | 80 | 75 | 65 | 75 | 70 | 70 | 65 | 73 |
| Pulse pressure | 25 | 20 | 20 | 15 | 25 | 10 | 35 | 25 | 10 | 35 | 20 | 30 | 23 |
| Nov. 24, 1917: | | | | | | | | | | | | | |
| Systolic | 90 | 100 | 100 | 90 | 90 | 90 | 90 | 90 | 90 | 100 | 80 | 90 | 92 |
| Diastolic | 75 | 65 | 65 | 70 | 55 | 70 | 85 | 65 | 75 | 80 | 65 | 65 | 70 |
| Pulse pressure | 15 | 35 | 35 | 20 | 35 | 20 | 5 | 25 | 15 | 20 | 15 | 25 | 22 |
| Dec. 8, 1917: | | | | | | | | | | | | | |
| Systolic | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 80 | 90 | 89 |
| Diastolic | 75 | 65 | 85 | 70 | 60 | 65 | 85 | 65 | 75 | 75 | 65 | 65 | 71 |
| Pulse pressure | 15 | 25 | 5 | 20 | 30 | 25 | 5 | 25 | 15 | 15 | 15 | 25 | 18 |
| Dec. 19, 1917: | | | | | | | | | | | | | |
| Systolic | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | ..... | 80 | 90 | 89 |
| Diastolic | 75 | 70 | 85 | 70 | 60 | 65 | 85 | 65 | 75 | ..... | 65 | 65 | 71 |
| Pulse pressure | 15 | 20 | 5 | 20 | 30 | 25 | 5 | 25 | 15 | ..... | 15 | 25 | 18 |
| Jan. 12, 1918: | | | | | | | | | | | | | |
| Systolic | 90 | 100 | 110 | 95 | 90 | 90 | 110 | 90 | 100 | ..... | 100 | 100 | 98 |
| Diastolic | 75 | 85 | 90 | 80 | 60 | 65 | 70 | 65 | 85 | ..... | 70 | 60 | 73 |
| Pulse pressure | 15 | 15 | 20 | 15 | 30 | 25 | 40 | 25 | 15 | ..... | 30 | 40 | 25 |
| Jan. 26, 1918: | | | | | | | | | | | | | |
| Systolic | 90 | 110 | 95 | 85 | 80 | 90 | 100 | 90 | 90 | ..... | 95 | 93 | 93 |
| Diastolic | 75 | 70 | 65 | 60 | 55 | 65 | 60 | 60 | 64 | ..... | 65 | 50 | 63 |
| Pulse pressure | 15 | 40 | 30 | 25 | 25 | 25 | 40 | 30 | 26 | ..... | 30 | 43 | 30 |
| Feb. 2, 1918: | | | | | | | | | | | | | |
| Systolic | 90 | 100 | 95 | 100 | 90 | 95 | 100 | 90 | 90 | ..... | 95 | 100 | 95 |
| Diastolic | 65 | 70 | 65 | 65 | 55 | 70 | 60 | 60 | 70 | ..... | 65 | 60 | 64 |
| Pulse pressure | 25 | 30 | 30 | 35 | 35 | 25 | 40 | 30 | 20 | ..... | 30 | 40 | 31 |

[1] All blood-pressure measurements were taken with the Tycos sphygmomanometer with the subject sitting.

[2] Blood-pressure measurements were obtained with *Fre* on Oct. 13, as follows: Systolic, 110; diastolic, 80; pulse pressure, 30.

[3] The averages for Oct. 27, omitting *Kon's* values, are as follows: Systolic, 100; diastolic, 72; pulse pressure, 28.

the diet period continued. The highest values for the systolic pressure were always found in the initial observation. In the majority of instances the highest values for diastolic pressure were likewise obtained at that time but some of the later records show a slight rise. The highest systolic pressure recorded, 140 mm., is that for *Kon* on October 27, 1917. It will be recalled that this subject had not then been subjected to a restriction in the diet, and hence this value represents for him a normal, unaffected blood pressure. A very striking fall in his blood pressure took place in the 2 weeks between the records of October 27 and November 10; that is, the systolic blood pressure fell from 140 mm. to 110 mm.

Considering first the systolic pressures, the difference between the initial record and the absolute minimum found during the experiment is as follows: *Bro*, 25 mm.; *Can*, 28 mm.; *Kon*, 50 mm.; *Gar*, 30 mm.; *Gul*, 38 mm.; *Mon*, 25 mm.; *Moy*, 30 mm.; *Pea*, 10 mm.; *Pec*, 30 mm.; *Spe*, 26 mm. (last observation December 8); *Tom*, 40 mm.; and *Vea*, 28 mm. If one uses the record at the end of the observations, these differences become somewhat smaller with all but *Bro*, *Pea*, and *Spe*. In other words, we note, roughly speaking, an average fall of 20 mm. systolic blood pressure from October 13 until the end of the experiment. We have every reason to believe that the blood pressure fell perceptibly in the 9 days between the beginning of the reduction in diet and October 13, so this 20 mm. represents a distinctly minimum value.

The average systolic pressures for all of the men are given in the last column of table 76. The irregularity in number of subjects, *i. e.*, 11 on the first and the last four dates, and 12 on the other dates, affects the averages but little. The high values for *Kon* on October 27 raise the averages for the three pressures about 3 mm.; the averages for that date without *Kon* are therefore given in a footnote. The maximum average systolic blood pressure is 115 mm. on October 13, while the minimum average is recorded for both December 8 and 19, *i. e.*, 89 mm., this being a total average fall of 26 mm.

The diastolic pressure likewise decreased profoundly, the initial and minimum values being as follows: *Bro*, 90 and 65 mm.; *Can*, 100 and 65 mm.; *Kon*, 90 and 65 mm.; *Gar*, 75 and 60 mm.; *Gul*; 75 and 55 mm.; *Mon*, 80 and 65 mm.; *Moy*, 70 and 60 mm.; *Pea*, 70 and 60 mm.; *Pec*, 85 and 64 mm.; *Spe*, 88 and 70 mm.; *Tom*, 80 and 65 mm.; *Vea*, 80 and 50 mm. In other words, diastolic blood pressures as low as 60 mm. appear with 5 of our subjects; all of the subjects except *Spe* show at some time during the experiment diastolic blood pressures of 65 mm. or less.

The average diastolic pressures, which are also subject to the slight irregularities of averaging noted for the systolic pressures, show a

maximum of 81 mm. on October 13 and a minimum of 63 mm. on January 26, a total fall of 18 mm. It is important to note that the average values for 11 men on January 26 and February 2 are 63 and 64 mm., respectively.

### SYSTOLIC AND DIASTOLIC BLOOD PRESSURE, SQUAD B.

Since we have no basal data for the men in Squad A, *i. e.*, measurements prior to dietetic restriction, the values found for Squad B have a special interest, as observations were made with these men the night preceding the beginning of their dietetic restriction (January 5, 1918). The data obtained for Squad B on January 5 and on the subsequent

TABLE 77.—*Blood-pressure measurements—Squad B.*

| Date and measurement.[1] | Fis. | Har. | How. | Ham. | Kim. | Lon. | Sch. | Liv. | Sne. | Tho. | Van. | Wil. | Av. for squad. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Normal diet.* | | | | | | | | | | | | | |
| Jan. 5, 1918:[2] | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* |
| Systolic | 120 | 138 | 120 | 110 | 105 | ..... | 142 | 120 | 120 | 105 | 130 | 105 | 120 |
| Diastolic | 90 | 80 | 80 | 80 | 80 | ..... | 90 | 80 | 80 | 75 | 90 | 85 | 83 |
| Pulse pressure | 30 | 58 | 40 | 30 | 25 | ..... | 52 | 40 | 40 | 30 | 40 | 20 | 37 |
| *Reduced diet.* | | | | | | | | | | | | | |
| Jan. 13, 1918: | | | | | | | | | | | | | |
| Systolic | 105 | 115 | 90 | 90 | 120 | 100 | 120 | 90 | 110 | 90 | 105 | 90 | 102 |
| Diastolic | 80 | 65 | 60 | 60 | 75 | 65 | 78 | 65 | 70 | 75 | 70 | 65 | 69 |
| Pulse pressure | 25 | 50 | 30 | 30 | 45 | 35 | 42 | 25 | 40 | 15 | 35 | 25 | 33 |
| Jan. 19, 1918: | | | | | | | | | | | | | |
| Systolic | 105 | 105 | 100 | 100 | 85 | 90 | 100 | 90 | 110 | 90 | 95 | 90 | 97 |
| Diastolic | 80 | 60 | 65 | 65 | 60 | 65 | 65 | 60 | 70 | 75 | 65 | 65 | 66 |
| Pulse pressure | 25 | 45 | 35 | 35 | 25 | 25 | 35 | 30 | 40 | 15 | 30 | 25 | 30 |
| Jan. 27, 1918: | | | | | | | | | | | | | |
| Systolic | 90 | 100 | 100 | 90 | 85 | 90 | 100 | 85 | 110 | 80 | 100 | 100 | 94 |
| Diastolic | 70 | 60 | 65 | 55 | 60 | 65 | 65 | 55 | 70 | 65 | 70 | 70 | 64 |
| Pulse pressure | 20 | 40 | 35 | 35 | 25 | 25 | 35 | 30 | 40 | 15 | 30 | 30 | 30 |

[1] All blood-pressure measurements were taken with the Tycos sphygmomanometer, with the subject sitting.

[2] Blood-pressure measurements were obtained with *McM* on Jan. 5, as follows: Systolic, 110; diastolic, 75; pulse pressure, 35.

nights, January 13, 19, and 27, 1918, are given in table 77. The normal values for systolic pressure obtained on January 5 ranged from 105 mm. with *Kim, Tho,* and *Wil,* to a maximum of 142 mm. with *Sch.* The average systolic pressure for the 11 men was 120 mm. The diastolic pressure for this date ranged from 75 mm. with *Tho,* to 90 mm. with *Fis, Sch,* and *Van.* The average diastolic pressure for the 11 men on this day was 83 mm.

One week later (January 13) the systolic pressure had fallen in every case, with the single exception of *Kim,* with whom there was an in-

crease of 15 mm. As a rule, the fall in systolic pressure was not far from 15 to 20 mm., the average systolic pressure for this date being 102 mm. Thus the contention is correct that the systolic pressure noted with Squad A on October 13, one week after the low diet began, represented a distinctly lower level than would have been found had these men been measured prior to the dietetic reduction. It is quite probable, therefore, that an addition of from 10 to 20 mm. to the average systolic blood pressure of October 13 with Squad A should be made to indicate the probable blood pressure of these men prior to dietetic reduction, although the total calories in the diet were much less proportionately with Squad B than with Squad A, and undoubtedly the drafts upon body-material were considerably greater for Squad B during this week. Nevertheless, there must have been a noticeable fall in systolic pressure with Squad A in the week which preceded October 13.

In the two weeks following January 13 there was with Squad B a distinct tendency for the systolic pressures to fall still lower. With *Fis* and *Har*, this fall was 15 mm.; with *How* a slight rise took place; with *Ham* the pressure rose, then fell again; with *Kim* the pressure fell in the later measurements from 120 to 85 mm., a fall of 35 mm. *Lon*, who was not included in the first measurements and hence was measured for the first time after a week's restriction in diet, showed essentially constant blood pressures for the rest of the experiment. With *Sch* a drop of 20 mm. occurred, with *Liv* but 5 mm., with *Sne* there was no further change, with *Tho* there was a drop of 10 mm., with *Van* the fall varied from 10 to 5 mm., and with *Wil* there was a tendency to a slight rise.

The average values given in the last column of table 77 are again open to criticism owing to the absence of *Lon* on January 5, 1918. The minimum average value is 94 mm. on January 27, with a total fall from normal of 26 mm. This minimum of 94 mm. compares with the 95 mm. found as an average value with Squad A on February 2, but is somewhat higher than the actual minimum of 89 mm. found on two nights (December 8 and 19) with Squad A.

Profound alterations in the diastolic pressure likewise appear, even in so short a period of undernutrition as three weeks. Comparing the records for the beginning and end of the observations we find that the diastolic pressure fell from normal with *Ham*, *Sch*, and *Liv*, 25 mm., with *Fis*, *Har*, *Kim*, and *Van*, 20 mm., with *Wil* and *How*, 15 mm., with *Sne* and *Tho*, 10 mm. Diastolic pressures of 65 mm. or below are noted with all of the subjects but *Fis* and *Sne*. The absolute lowest value was 55 mm. which was found with *Ham* and *Liv* on January 27.

The average diastolic pressure for 11 men prior to the restricted diet was 83 mm. on January 5, 1918, and the lowest average diastolic pressure was 64 mm., this occurring on the last day. This average

value of 64 mm. is exactly that noted with Squad A. It is of special interest that one week of a reduced diet, containing only 1,400 net calories, lowered the systolic pressure of 11 men from 120 to 102 mm. and the diastolic pressure from 83 to 69 mm.

### PULSE PRESSURE, SQUADS A AND B.

The average normal pulse pressure (*i. e.*, the difference between systolic and diastolic pressures) of college students of this age and environment is shown in table 77 by the values found on January 5 with Squad B, namely, 37 mm. with a range from 20 to 58 mm. Before considering the pulse pressures with Squad A we may advantageously examine those with Squad B. These show a slight tendency to fall (7 mm. on the average) as the restricted diet progressed and increased in only two cases. With Squad B, the normal pulse pressure was not far from 37 mm. Comparing this value with the pulse pressures for Squad A given in table 76, we find that with the prolonged reduction in diet there is a tendency toward much lower pulse pressures with not a few of the men in this squad. *Bro* shows a low pulse pressure of 15 mm. in many of the measurements, *Can* one record of 15 mm., *Kon* two records of 5 mm., and *Gar* two records of 15 mm. The lowest record for *Gul* was 25 mm., *Mon*, 10 mm. *Moy*, 5 mm., *Pea*, 25 mm., *Pec*, 10 mm., *Spe*, 15 mm., *Tom*, 15 mm., and *Vea*, 25 mm. The group averages in the last column of the table show that the pulse pressures regularly decreased from 34 mm. on October 13 to 18 mm. on December 19, but after the return from the Christmas vacation, the pulse pressure rose for the whole squad to 25 mm. with the two final values somewhat higher, *i. e.*, 30 and 31 mm. It is quite clear that a large proportion of the values shown in table 76 are distinctly lower than normal; hence we may consider that as a result of the low diet there was a definite tendency towards a decrease in the pulse pressure, as well as an absolute decrease in not only the systolic but likewise the diastolic pressure. *Pea*, a well-trained athlete, retained a remarkably constant pulse pressure throughout the entire series of observations. That the pulse pressures of Squad A are noticeably lower than those of Squad B is clear in spite of the almost identical systolic, diastolic, and pulse pressures of both squads on the first day of the experiment. The relationship between these lower values and the exact metabolic level is worthy of special attention in further work.

### MODERATE MUSCULAR WORK AND BLOOD PRESSURE, SQUAD A.

It is especially important to note the influence of moderate activity upon the heart, particularly upon the blood pressure, as shown by careful measurements of blood pressure prior to a walking period and immediately following the walking period for the several men. To secure a base-line, the cuff was adjusted prior to the walking test and

a number of observations made with the subject in the standing position. After the completion of the walking, which usually occupied about 26 minutes, the cuff was immediately inflated and both the systolic and diastolic blood pressures noted. At the end of one minute a second observation was made, and the observations continued at intervals for 2 to 2½ minutes. These measurements, it is only fair to state, were taken under very great tension on the part of all operators and are not so free from extraneous influences as one could wish. Furthermore, the cuff had to be repeatedly inflated somewhat rapidly, and there was hardly time for the circulation to be fully established in each case.[1] On the other hand, it is highly improbable that with the group of men as a whole, any disturbance of the general picture could have been made by a fault in technique. The readings were frequently checked by one of us and we have every confidence that they were both taken and recorded as accurately as they could be under the experimental conditions. We believe that they present a true picture of the blood pressures immediately following walking at a rate of about 69 meters per minute. The effects of walking upon the action of the heart will be further considered in the discussion of the pulse-rate. (See p. 440.)

Although the first records of the blood pressures before and after walking were those for Squad B on the morning of January 28, we shall first discuss the values found with Squad A on the morning of February 3, 1918. These are given in table 78, in which both systolic and diastolic pressures and pulse pressure are recorded for each of the 11 men immediately before and after walking. Usually two additional observations were made after the cessation of walking at about the fifth and ninth minutes with the subject sitting. The systolic blood pressures as measured on these men in the standing position before work on the morning of February 3 may first be compared with the records made by Dr. Goodall on the evening of February 2 for the sitting position. The systolic pressures on the morning of February 3 averaged 101 mm., the highest being 107 mm. with *Mon* and the lowest 97 mm. found with 4 of the subjects. Examining the sitting blood pressures found the preceding evening (see those for February 2 in the lower part of table 76), we find that the values tend to be somewhat below 100, with an average of 95 mm. The highest, 100 mm., was found with *Can*, *Gar*, *Moy*, and *Vea*, and the lowest, 90 mm., with *Bro*, *Gul*, *Pea*, and *Pec*. Although the effect of posture on blood pressure is the subject of much discussion, the morning systolic blood pressures are reasonably well checked by these observations of the evening before. The morning values for the systolic blood pressure taken just before walking are therefore in all probability not far from the true values.

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[1] This criticism also applies to the technique used by Cotton, Rapport, and Lewis, Heart, 1917, 6, p. 269.

TABLE 78.—*Blood-pressure measurements prior to and immediately after 24 minutes of level walking on a treadmill—Squad A, February 3, 1918.*

| Subject and measurement. | Standing. | | | | | | Sitting. | |
|---|---|---|---|---|---|---|---|---|
| | Average before walking. | After walking ended. | | | | | After walking ended. | |
| | | ½ min. | 1 min. | 1½ min. | 2 min. | 2½ min. | 5 min. | 9 min. |
| *Bro:* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* |
| Systolic | 97 | 100 | 100 | 100 | 98 | ....... | 100 | 96 |
| Diastolic | 81 | 78 | 76 | 82 | 82 | ....... | 80 | 78 |
| Pulse pressure | 16 | 22 | 24 | 18 | 16 | ....... | 20 | 18 |
| *Can:* | | | | | | | | |
| Systolic | 97 | 108 | 108 | 106 | 104 | ....... | 104 | 104 |
| Diastolic | 74 | 72 | 76 | 78 | 78 | ....... | 76 | 80 |
| Pulse pressure | 23 | 36 | 32 | 28 | 26 | ....... | 28 | 24 |
| *Kon:* | | | | | | | | |
| Systolic | 106 | 102 | 104 | 104 | 104 | ....... | 102 | 98 |
| Diastolic | 78 | 80 | 86 | 88 | 86 | ....... | 80 | 78 |
| Pulse pressure | 28 | 22 | 18 | 16 | 18 | ....... | 22 | 20 |
| *Gar:* | | | | | | | | |
| Systolic | 106 | 110 | 110 | 110 | 110 | 108 | 106 | 106 |
| Diastolic | 71 | 62 | 64 | 70 | 74 | 76 | 70 | 68 |
| Pulse pressure | 35 | 48 | 46 | 40 | 36 | 32 | 36 | 38 |
| *Gul:* | | | | | | | | |
| Systolic | 104 | 100 | 100 | 102 | 100 | ....... | 98 | 102 |
| Diastolic | 76 | 66 | 68 | 68 | 70 | ....... | 66 | 66 |
| Pulse pressure | 28 | 34 | 32 | 34 | 30 | ....... | 32 | 36 |
| *Mon:* | | | | | | | | |
| Systolic | 107 | 106 | 106 | 108 | 108 | ....... | 106 | 104 |
| Diastolic | 72 | 66 | 68 | 70 | 70 | ....... | 68 | 72 |
| Pulse pressure | 35 | 40 | 38 | 38 | 38 | ....... | 38 | 32 |
| *Moy:* | | | | | | | | |
| Systolic | 102 | 110 | 112 | 112 | 112 | ....... | 108 | 106 |
| Diastolic | 68 | 70 | 68 | 70 | 72 | ....... | 66 | 70 |
| Pulse pressure | 34 | 40 | 44 | 42 | 40 | ....... | 42 | 36 |
| *Pea:* | | | | | | | | |
| Systolic | 97 | 100 | 100 | 98 | 96 | ....... | 100 | 100 |
| Diastolic | 79 | 60 | 58 | 56 | 54 | ....... | 66 | 72 |
| Pulse pressure | 18 | 40 | 42 | 42 | 42 | ....... | 34 | 28 |
| *Pec:* | | | | | | | | |
| Systolic | 97 | 106 | 106 | 102 | 102 | ....... | 100 | 102 |
| Diastolic | 60 | 76 | 76 | 76 | 76 | ....... | 68 | 66 |
| Pulse pressure | 37 | 30 | 30 | 26 | 26 | ....... | 32 | 36 |
| *Tom:* | | | | | | | | |
| Systolic | 99 | 102 | 102 | 100 | 100 | 98 | 98 | 100 |
| Diastolic | 75 | 66 | 68 | 70 | 70 | 72 | 70 | 72 |
| Pulse pressure | 24 | 36 | 34 | 30 | 30 | 26 | 28 | 28 |
| *Vea:* | | | | | | | | |
| Systolic | 100 | 100 | 100 | 102 | 100 | 100 | 98 | 102 |
| Diastolic | 64 | 68 | 70 | 70 | 72 | 74 | 66 | 66 |
| Pulse pressure | 36 | 32 | 30 | 32 | 28 | 26 | 32 | 36 |
| Average: | | | | | | | | |
| Systolic | 101 | 104 | 104 | 104 | 103 | ....... | 102 | 102 |
| Diastolic | 72 | 69 | 71 | 73 | 73 | ....... | 71 | 72 |
| Pulse pressure | 29 | 35 | 33 | 31 | 30 | ....... | 31 | 30 |

The diastolic blood pressures likewise show values in the morning which are, as a rule, higher than those found the evening before. That is, in the morning records with the subject standing we find the diastolic blood pressure ranges from 81 mm. with *Bro* to a

minimum of 60 mm. with *Pec*, the average value being for the morning 72 mm. The average of the records made by Dr. Goodall the evening before is 64 mm. Nevertheless, the appearance of values as low as 60 mm. in the case of *Pec* and 64 mm. in the case of *Vea* is a reasonable control upon the low values found the evening before.

The pulse pressures taken before work on February 3 are not unlike those found the evening before. The morning pulse pressures, with the subject standing before work, range from a minimum of 16 mm. with *Bro* to a maximum of 37 mm. with *Pec* and average 29 mm. On the evening before they ranged from a minimum of 20 mm. with *Pec* to a maximum of 40 mm. with *Moy* and *Vea*, and average 31 mm. A somewhat interesting fact is that *Pec* had the minimum pulse pressure in the evening but gave the maximum value the next morning prior to walking.

The effect of work upon the blood pressure can in this series of measurements be noted only in the measurement of the blood pressure in the first quarter minute after the cessation of walking. These values are likewise recorded in table 78. In this first observation immediately after work a slight tendency is shown for the systolic pressure to rise in nearly all cases, although only a few millimeters, the most pronounced rise being 11 mm. with *Can*. In three cases there is a slight fall. Comparing the average systolic pressure for the 11 men the first quarter minute after the end of work with that measured before work, we find a rise of but 3 mm., *i. e.*, from 101 to 104 mm. The course of the systolic blood pressure in the next 2 minutes was essentially constant, there being hardly any changes that are truly significant, although in general there was a very slight tendency for the blood pressure to fall as time progressed. The two observations made with the subject in the sitting position show slightly lower values than those found for the standing. Except for *Can* and *Kon*, the pre-walking blood pressure level was usually regained at the end of 9 minutes. With *Can* the blood pressure remained at 104 mm. as compared with 97 mm. before walking and with *Kon* it was 98 mm. as compared with 106 mm., these men showing diametrically opposite effects. The fact should be noted, however, that the values compared were obtained in different positions.

For comparison with the values cited here, we have systolic blood pressures following walking which were obtained with a normal subject in the standing position in the course of another research some years ago. With this subject (a normal individual walking at the rate of 90 meters per minute for approximately 20 minutes) the general tendency for the systolic blood pressure was to show an increase of 3 to 8 mm. in the first observation after cessation of walking.

With the diastolic pressure for Squad A the immediate effect of work was usually to lower the pressure measurably, although *Pec* shows a rise of 16 mm. Practically all the other men show either a very slight rise or a pronounced fall. A lowering of 9 or more millimeters may be noted in the case of *Gar*, *Gul*, *Pea*, and *Tom*, the fall with *Pea* being 19 mm. The average diastolic pressures before work and the first quarter minute after work were 72 and 69 mm., respectively. The subsequent course of the diastolic blood pressure usually tended towards a slight rise, being in 9 cases higher at the end of 2 minutes than at the end of the first quarter minute. With *Gar* it rose from 62 to 76 mm. in 2.5 minutes and with *Tom* from 66 to 72 mm. With most subjects there was a tendency for the diastolic blood pressure to fall when the sitting position was assumed. At the end of 9 minutes after work, with the subject in the sitting position, the diastolic pressure was usually not far from that for the standing position prior to work, although some rather striking exceptions to this may be noted in the cases of *Gul*, *Pea*, and *Pec*. Especially worthy of note are the low values of 58, 56, and 54 mm. noted with *Pea*. These values are absolutely lower than any diastolic blood pressures heretofore noted with this subject, the lowest diastolic value shown in table 76 with this man being 60.

The immediate effect of work on the pulse pressure was in all but three instances a noticeable rise to an average pulse pressure of 35 mm. as compared with 29 mm. before work. The greatest rise was found with *Pea*, the pulse pressure changing from 18 to 40 mm., *i. e.*, an increment of 22 mm. *Kon*, *Pec*, and *Vea* show falls of 6, 7, and 4 mm., respectively. The subsequent records indicate a definite tendency for the pulse pressure to fall as time passed. No great difference is noted when the subject changed to the sitting position. At the end of 9 minutes the pulse pressure is usually not far from that prior to work, except in the values found for *Kon*, *Gul*, and *Pea*.

## MODERATE MUSCULAR WORK AND BLOOD PRESSURE, SQUAD B.

Observations on systolic, diastolic, and pulse pressures were made with Squad B before and immediately after walking on the morning of January 28, 1918. The data secured are recorded in table 79. A comparison of the values for the systolic pressure before walking with those obtained with the same subjects the evening before, (see table 77) is of interest. For the most part there is no great difference between the two series although certain of the men, particularly *Kim* and *Sch*, show very considerable increases over the evening record. The average for the systolic pressure for the evening of January 27 was 94 mm. and for the morning of January 28, 101 mm.

The effect of walking was determined, as before, by observing the blood pressures in the first 15 seconds after the cessation of walking.

TABLE 79.—*Blood-*[illegible] *and* *after 24 minutes of level* *1918.*

1 3 min. after walking ended; systolic, 104 mm., diastolic, 80 mm., pulse pressure, 24 mm.

2 *Wil*, sitting, 6 min. after walking ended; systolic, 90 mm., diastolic, 64 mm., pulse pressure, 26 mm.; 10 min. after walking ended, systolic, 90 mm., diastolic, 66 mm., pulse pressure, 24 mm.

which must first be thoroughly cleared by careful accumulation of experimental evidence. Diastolic blood pressures so close to the shock level as those observed with several of these men would imply that the dietetic conditions in this research might be somewhat near the border line of safety. Obviously, low blood pressure brought about by dietetic alterations must be thoroughly studied in all its phases before final deductions can be made.

## PULSE-RATE.

The intimate relationship between the mechanism of the circulatory system and the total metabolism has been frequently pointed out in publications from the Nutrition Laboratory. The heart rate is, with the same individual, a remarkably significant index of the total metabolism. When it is considered that the total carbon-dioxide production is directly proportional to muscular activity and heat production, and furthermore that the blood must carry away the carbon dioxide and supply fresh oxygen to the tissues, in proportion to the need therefor, it is not surprising that the work of the heart bears a general relationship to the total metabolism. If the systolic discharge from the heart were uniform under all conditions, one could predicate that the pulse-rate would be proportional to the total metabolism. Such a proportionality of relationship, however, is by no means established or to be inferred from experimental evidence thus far obtained.

While a reasonably close correlation between the pulse-rate and the total metabolism of a given individual appears to be substantiated by a large number of experiments, this does not apply in any sense to a comparison of the pulse-rate and total metabolism of different individuals. For example, when a subject has a pulse-rate of 60 at one time and a pulse-rate of 80 at another time, one can be sure that the metabolism will be measurably higher with the higher pulse-rate, but it is by no means certain that subject A with a pulse-rate of 60, even with an equivalent weight and height, will have a metabolism lower than subject B of the same height and weight with a pulse-rate of 80. Indeed, the absence of correlation between pulse-rate and total metabolism with different individuals has been frequently noted and commented on in this Laboratory. On the other hand, a recent biometric treatment[1] of the basal metabolism data of the Nutrition Laboratory has indicated the existence of a slight but apparently significant correlation between these two variables, slightly higher gaseous exchange being associated with higher pulse-rate, even with men and women in complete muscular repose and in the post-absorptive state.

In this research on low diet it was imperatively necessary to obtain every possible index of metabolism or physiological activity

[1] Harris and Benedict, Carnegie Inst. Wash. Pub. No. 279, 1919, p. 79.

TABLE 90.—*Daily pulse-rate*[1] *of Squad A.*

[Subjects in lying position, without food.]

[1] These observations were made early in the morning at least 12 hours after the last meal and for the most part are averages of a considerable number of pulse-rates taken during the two periods on the respiration apparatus.

[2] These records were obtained with *Fre* who left Squad A on Oct. 25.

[3] Day following this date was an uncontrolled Sunday; no record taken.

[4] *Kon* was on normal diet on this day, and hence this pulse-rate is not included in the average.

[5] *Spe* on Oct. 27 believed he had a touch of grippe; this pulse-rate not included in the average.

TABLE 80.—*Daily pulse-rate*[1] *of Squad A*—continued.

[Subjects in lying position, without food.]

[1] These observations were made early in the morning at least 12 hours after the last meal and for the most part are averages of a considerable number of pulse-rates taken during the two periods on the respiration apparatus.

[2] Records on this date taken in Boston in the group respiration chamber.

[3] Thanksgiving recess, Nov. 29 to Dec. 2 inclusive.

[4] Christmas recess, Dec. 20 to Jan. 6, inclusive.

TABLE 80.—*Daily pulse-rate*[1] *of Squad A*—continued.

[Subjects in lying position, without food.]

[1] These observations were made early in the morning at least 12 hours after the last meal and for the most part are averages of a considerable number of pulse-rates taken during the two periods on the respiration apparatus.

[2] Records on this date taken in Boston in the group respiration chamber.

[3] Note that for these subjects the maximum occurs in January; with the others it appears early in the series.

during the period with the reduced diet. Comparing the rates prevailing at the beginning of the experiment with normal diet and those at the end of January with reduced diet, we find a pronounced fall in pulse-rate in every instance. This striking reduction in pulse-rate is so great with most of the subjects that frequent observations are recorded of pulse-rates between 35 and 40 per minute and even lower. To lay particular emphasis upon the low rates, all values between 40 and 36 inclusive are printed in italics, and the values of 35 or below in bold-face type. An inspection of the table shows the incidence of the italicized figures as the study progressed. The members of the squad with whom italicized figures occur increase in number with the length of the period of reduced diet until, in the last week in November, 8 of the squad show values of 40 or below. As a matter of fact this represents the minimum pulse for the squad as a whole. At the end of the experiment, 5 men show values of 40 or below, but the number of low counts is somewhat less than those which appear in the table in the latter part of November.

Special emphasis should be laid upon the appearance of the bold-face figures indicating 35 counts or below. These are found with 5 subjects during the month of November and in the latter part of January. Records of 32 or below appear in 4 cases in November and the absolute minimum was clearly and definitely established with *Vea* on November 19 of 29 beats, this record being the average of a series of 6 counts. The actual counts for this particular subject on November 19 were: 30, 29, 29, 28, 29, and 30. Thus we have

four separate counts of 29 or 28. After several months' personal practice in counting his own pulse-rate, in which he had been frequently checked by one of our observers, this subject made a report that on January 31 he counted his pulse while sitting in the class room at $10^h15^m$ a. m. and found it to be 32 per minute; later at $11^h30^m$ a. m., after lying down about 4 minutes in his room, he found the pulse-rate as counted by himself to be 28 beats per minute. It thus seems definitely established that we have with this subject a clear case of a pulse-rate which on two occasions was below 30 beats per minute.

The fluctuations in pulse due to the novelty of the situation and slight psychological disturbances are perhaps best shown in the 7 days prior to the reduction in diet. In a sense, the average of these days may be considered as the average resting pulse of these men prior to dietetic restriction. In the majority of cases such an average would be legitimate, but in the case of *Vea* the pulse-rate on the first three days is obviously higher than on the last three days of the normal diet period. The period of the lowest pulse-rate with the squad as a whole occurred in the week between November 17 and November 25, inclusive. The average pulse-rate of these men prior to the reduction in diet may profitably be compared with the average for this week to determine the maximum average change in pulse-rate. This is done in table 81.

TABLE 81.—*Comparison of pulse-rate during normal diet with the lowest level of pulse-rate during reduced diet*[1]*—Squad A.* (Weekly averages.)

[Subjects in lying position, without food.]

| Subject. | Normal diet, Sept. 27 to Oct. 4, 1917. | Reduced diet, Nov. 17 to 25, 1917. | Difference between normal and minimum pulse-rate. | Subject. | Normal diet, Sept. 27 to Oct. 4, 1917. | Reduced diet, Nov. 17 to 25, 1917. | Difference between normal and minimum pulse-rate. |
|---|---|---|---|---|---|---|---|
| Bro..... | 57 | 52 | 5 | Pec...... | 51 | 34 | 17 |
| Can..... | 57 | 43 | 14 | Spe...... | 56 | 44 | 12 |
| Gar..... | 49 | 40 | 9 | Tom..... | 68 | 47 | 21 |
| Gul..... | 59 | 43 | 16 | Vea...... | 50 | 34 | 16 |
| Mon..... | 61 | 51 | 10 | | | | |
| Moy..... | 57 | 36 | 21 | Av... | 56 | 42 | 14 |
| Pea..... | 51 | 35 | 16 | | | | |

[1] See table 80 for the material from which these data have been drawn.

Using as a basis of comparison the average pulse-rate from September 27 to October 4, when the subjects were on normal diet, we find in all cases a fall in pulse-rate due to the diet, although the differences, of course, are not so large as the differences between the maximum and minimum noted in table 80. The smallest drop was with *Bro* (5 beats) and the maximum with *Moy* and *Tom* (21 beats). On the average the pulse-rate was lowered 14 beats or 25 per cent.

It is thus seen that the general picture of a marked fall in pulse-rate is indicated in every case; the only variations are in the degree of the fall. A comparison between the maximum normal pulse and the minimum pulse found on any day of reduced diet would indicate the maximum variations for the subjects.

When it is remembered that the pulse-rates recorded in table 80 are the average of not less than 3 and for the most part 6 or more counts, it is seen that we deal here not with isolated 1-minute counts, but with a true representation of the pulse level for that particular day. That fluctuations occurred from time to time from uncontrollable causes, even during the morning, was frequently noted by some of our observers. Such illustrations were sometimes recorded by one of the student observers, Mr. Charles Wesley Davis, who assisted in the pulse counts at Springfield. From his thesis prepared in connection with his college work, we have selected for record here the following instances of somewhat rapid changes in pulse-rate during the morning experiments.

On October 24, while *Pec* was resting on the cot during the morning experiment, a sudden nervous impulse caused him to kick his leg. As a result, his pulse-rate jumped from 42 to 52 for a minute. When *Kon* first came on the squad for experimentation, Dr. Roth spoke to him about keeping awake. His pulse, which had been 44, immediately went to 58. *Gul* had a habit of taking occasional deep yawns during his morning tests. His pulse always went up after such a yawn, his average rise being from 6 to 10. *Mon* and *Tom* were examples of men whose pulse fluctuated at intervals for no apparent reason. Upon questioning the men, it was often found that they had been thinking of something exciting. A striking example of the psychical effect upon the pulse was noted with *Gar* on November 14. His pulse-rate rose from 36 to 50, yet he remained perfectly quiet. He admitted later he had been thinking about an examination that was due on the same morning and was doubtful about his knowledge of the subject. *Mon's* pulse showed sudden and wide variations from slight changes in body position. When he first lay down on the cot January 30, his pulse was 56 per minute. Eleven minutes later he was asleep with a pulse-rate of 46. After he changed to another cot and the mask was attached for the respiration experiment, his pulse went to 54.

The maximum and minimum pulse-rates, with differences, are shown at the bottom of table 80. Usually the maximum occurred during the first week, when the subject was on a normal diet. Certain exceptions to this are noted in the footnotes. In some instances the pulse-rate was reduced nearly one-half, notably so in the case of *Vea* and *Kon*. It should furthermore be noted that the maximum with *Kon* occurred immediately after his return from the Christmas holidays. The same is true for the absolute maximum for *Can* and *Tom*. The subsequent course of the pulse during January, however, with neither *Kon* nor *Tom* reached as low a level as was recorded earlier, although with *Kon* a subsequent value as low as 38 was obtained. In general, it

may be stated that, from the data in table 81, the pulse-rate was reduced approximately one-fourth.

Such a striking change in pulse-rate is wholly inconceivable and, indeed, outside the experience of any clinicians with whom we have conferred. Furthermore, the literature rarely mentions pulse-rates as low as were frequently observed in these series, except with primarily pathological cases, and no study of general malnutrition or undernutrition with which we are familiar indicates such profound alterations. We evidently have to deal here with a distinct physiological level, with accompanying conservation of circulatory activity or, as subsequent discussion of the total metabolism will show, the low pulse level is the natural consequence of a lowered metabolism and hence shows a marked decrease in the circulatory activity. In any event, as indications of the pulse-rate of young men who are apparently normal, active and healthy, carrying out with no appreciable reduction in stamina or vigor their intellectual and physical collegiate activities, these values are, we believe, without comparison anywhere in physiological literature.

The tendency for the average minimum pulse-rate to coincide with the minimum food intake and minimum weight may be noted by comparing the dates of the average minimum pulse-rates, namely, November 17 to 25, with the body-weight curves and with the food intake at this time. The subsequent tendency to increase, which became marked during January, is undoubtedly due in part to the freedom allowed the men during the Christmas vacation. On the first day following the Christmas recess *Can*, *Kon*, and *Tom* showed their highest pulse-rates for the whole experiment, *i. e.*, 68, 61, and 74, respectively. With all of the subjects except *Moy* and *Bro*, the first pulse-rates observed after the Christmas recess were markedly higher than the last rate registered prior to the recess. This increment in the case of *Can* was 18, *Kon* 20, *Gar* 11, *Gul* 9, *Mon* 6, *Pea* 9, *Pec* 5, *Tom* 25, and *Vea* 10. With *Bro* there was a decrease of 2 and with *Moy* of 3. As a prime indication of the increased metabolism, these increases in pulse-rate may be directly ascribed to the uncontrolled diet during the Christmas recess.

### AVERAGE DAILY PULSE-RATE, SQUAD A.

Although the legitimacy may be questioned of comparing daily average values when the number of subjects used for averaging varied, as they do here, since *Fre*, *Kon*, and *Spe* did not serve for the whole period and the daily pulse records are not continuous, even with the other subjects, we have for purposes of comparison included the daily averages in table 80. It will be recalled that the pulse-rate was usually recorded for 9 subjects each morning and that on the few mornings following the experiments in the group respiration chamber in Boston,

the pulse-rates for the entire squad were measured. Usually the averages given in the last column of table 80 are those for not less than 8 or 9 subjects. The maximum average daily value of 58 beats appears on September 27 (the first day of the experiment). This figure represents an average value for 9 subjects. The minimum average daily value of 38 beats is noted twice, first on November 19 and again on January 28. On the latter date, however, the average represents but 4 subjects, while on November 19 daily pulse-rates for 9 subjects are included in the average. Three italicized figures, *i. e.*, 38, 40, and 40, appear in this column between November 19 to 24, and two appear in the last of January.

Beginning with October 7, that is, the third day after the reduced diet began, the average pulse-rate drops to 51 and continues to be reasonably uniform throughout October. There is a fall to 44 on October 31 and until November 19 the rate remains not far from 44. There is then a short period of low values, but throughout the month of December the average value of 44 or 45 beats is almost uniformly noted, the exceptions being December 9, 10, 11, and 13. A striking increase in the average value is noted on the first few days after the Christmas recess, January 7 to 9, when values of 54, 51, and 53 are found. There is then a progressive decrease, the lowest level occurring from about January 24 to 28, with a tendency for a slight rise thereafter. Apparently when these men are on their maintenance diet at the lower level, the average pulse-rate for the entire group is not far from 43 or 44 beats per minute. While, as we have stated, this method of averaging is open to criticism, the general influence of the reduced diet upon the squad as a whole is fairly well depicted by this series of daily averages. The daily records for each member of Squad A essentially correspond with the course of the general daily average. While certain of the men did not reach a particularly low level in pulse-rate, they nevertheless showed a general decrease in pulse-rate. With other men in Squad A extraordinarily low values were obtained. The profound influence of the reduced diet upon the pulse-rate is thus shown by inspection of the figures for the individual men, but it is shown by the daily averages more clearly and with less contamination by minor extraneous factors.

Save on a few days, all of the pulse records in table 80 were taken at Springfield. On certain of the Sundays in Boston pulse-rates were taken in the group chamber before the subjects rose in the morning. When compared, we find that the Boston values do not differ materially from those obtained on the day before and the day after in Springfield. For instance, on November 25, the average daily pulse-rate for the group obtained in Boston was 41, while the Springfield value for the day before was 40. That for the day following (47) is not unusual, and indicates the rise following the Sunday with uncontrolled diet.

On December 9 in Boston the pulse-rate averaged 47, the day before in Springfield 44, and the following day, also in Springfield, 50. On December 20 the rate obtained in Boston was 44 and the day before 43. On January 13 the rate in Boston was 48, the day before 52, and the following day 50. On January 27 the average rate in Boston was 42, the day before 42, but the following day, only 38. This last average is made up of values obtained from only 4 men, three of whom had consistently low pulse-rates. The final value for February 3 of 45 is the same as that for February 2 obtained in Springfield. The somewhat different conditions obtaining in the Boston experiments (see p. 491) were thus not sufficient to affect materially in either direction the average pulse-rates. It therefore seems perfectly justifiable to include them among the average pulse-rates in table 80.

### BASAL PULSE-RATE WITH LYING POSITION, SQUAD B.

Basal pulse-rates were also obtained for Squad B in the group respiration chamber in Boston, both for the normal period and during restriction in diet. They find subsequent use in a comparison of the positions of lying and standing on page 413. Although fewer in number than those of Squad A, they deserve presentation here, and are recorded in table 82. It will be seen that on two days the sub-

TABLE 82.—*Basal pulse-rate*[1]—*Squad B.*

[Subjects in lying position and without food.]

[1] Obtained in group respiration chamber before 6 a. m.

[2] On Dec. 16 three substitutes, not regular members of Squad B, showed the following pulse-rates: *Leo*, 64; *McD*, 54; *McM*, 73.

[3] On Jan. 6, *McM* had a pulse-rate of 63.

jects were with normal diet, although January 6 is characteristic of being the first observation after the Christmas recess. It may not be without significance that the average pulse-rate of this group showed an increase of 3 beats on the return of the men from the Christmas recess; it will be recalled that a pronounced increase was also found with Squad A under these conditions. Of special significance, however, are the values found on the three subsequent days with reduced

diet. On January 14 all the men except *Sne* showed a reduction in pulse-rate from the basal values found on January 6, this reduction for the squad as a whole averaging 8 beats. On January 20 a further reduction was noted in all but two cases, *Lon* showing no change and *Ham* showing an increment of 2 beats per minute. The average decrease for the entire squad was 5 beats. On January 28 a still further reduction was noted. On the average it decreased from 43 to 40, although with 3 individuals the pulse-rate increased on this date. At the bottom of table 82 are given both the maximum and minimum values, together with the differences. The average difference between maximum and minimum is 18 beats, showing for this squad a maximum decrease in the pulse-rate of 18 beats. This is in full conformity with the picture presented by the extensive data with Squad A.

## STANDARD ELECTROCARDIOGRAMS.

The pulse-rate data, which have been presented and discussed in preceding pages, were in all cases recorded from counts at the wrist. During the collection of these data, no subject or observer ever noted irregularity at the time of making the pulse counts. There were no apparent cardiac symptoms, even after hard muscular work. (See page 453.) The pulse-rate appeared to decrease with fair regularity with the progress of the experiment. It seemed highly improbable that the slow rates of 35 or less were due to disturbances in conduction such as a regular 2 : 1 heart block, *i. e.*, failure for every other auricular impulse to get through to the ventricles, or to the complete dissociation of auricles and ventricles characteristic of the Stokes-Adams syndrome. In the latter case, it is well known that the independent rate of the ventricles is usually about 32 per minute. Convincing proof in this matter of the normality of heart action in these slow pulse-rates associated with reduced diet could of course be had through graphic records, such as electrocardiograms taken under standard conditions.

It was desirable to interfere as little as possible with the Boston experimental program. This work could not be done in Springfield, and rather than take electrocardiograms from every subject, it appeared more satisfactory to take such tracings from only the 4 or 5 subjects who showed the slowest pulse-rate. Connections were therefore arranged from the string galvanometer in the main psychological laboratory to the group respiration chamber in the calorimeter room. The electrodes used in the respiration chamber were of the non-polarizable, wick form. A long strip of cotton gauze soaked in a saline solution was wrapped about the arm and the end of this dipped into a vessel of the saline solution. The distance between the arm and the vessel was about 7 inches. A porous clay cup containing the amalgamated zinc electrode and zinc sulphate was also placed in the vessel of saline solution. Such electrodes were connected with each arm, while

The tracings for the two days from the standard leads designated $L^1$, $L^2$, and $L^3$ are shown in table 83 as pulse-rates per minute. These range from 35 to 54; in the case of every subject lower pulse-rates were found at some other time during the investigation. This would naturally be expected. The subjects were thoroughly accustomed to having the pulse counted at the wrist, but this was not the case with the electrocardiographic tracings. Furthermore, both of the dates, December 20 and February 2, came at the end of a period of weight maintenance, during which time the amount of food was somewhat larger than at other periods. Since there was a noticeable correlation between the height of the pulse-rate and the energy intake, it could not be expected that the pulse would be as low here as it was, for example, at the middle of November. Nevertheless, the pulse-rates in the tracings which were made are mostly on a definitely lower plane than is commonly accepted as the normal pulse-rate for men of this age. The records taken in the chamber before the men got out of bed show especially slow rates, being 35 to 38 for the three men, *Kon*, *Pea*, and *Pec*.

TABLE 83.—*Pulse-rates shown by the standard electrocardiograms.*

If there were any pathological conditions to be found in the electrocardiographic tracings with the subjects on whom we took records in this low diet investigation, we would deem it necessary as important data of the experiment to publish all the tracings. Several of the tracings with explanatory legends are presented in figures 88, 89, and 90. In selecting the illustrations our only preference was to show those tracings which demonstrated the slower pulse-rates. Only normal electrocardiograms were shown by all of the subjects in every lead.

The usual chief deflections, *P*, *R*, and *T*, are present in their normal sequence and with no appreciably altered time relations. The waves are regular and of usual amplitude, and in no case is any certain wave absent or present in excessive number, that is, there are no extra systoles. There is no pathological arrhythmia, and absolutely no indication of heart block. Thus it is certain that the standard electrocardiograms demonstrate no abnormality other than the slow rate. The condition would appear to be classifiable as a sinus Bradycardia. This condition of slow, regular pulse-rate is known to occur normally in convalescence, old age, and pregnancy. These standard electrocardiograms taken in connection with our research seem to demonstrate that sinus Bradycardia may also normally occur with a lowered

metabolism resulting from reduced diet. Since the electrocardiograms indicate normal heart action, it would appear that in addition to such factors as sex and age we must also add nutritional level as exercising a prominent influence upon the pulse-rate level. It is important that the conditions found in this experiment may exist with no cardiac discomfort or dyspnea.

### PULSE-RATE, WITH LYING POSITION, PRIOR TO WORK OF BICYCLE RIDING.

The pulse-rates thus far considered were all obtained with the subject lying in the morning before breakfast and represent the minimum basal values.[1] In connection with the study of the return of the heart to normal after a definite amount of moderately vigorous physical exercise, Professor A. G. Johnson, of the faculty of the International Y. M. C. A. College at Springfield, determined the pulse-rates of the subjects in the lying position. His procedure in these experiments was as follows: After the subject came to the room containing the ergometer, he lay down on a table and the radial pulse was taken every minute until at least three successive observations gave the same rate. This usually required from 4 to 10 minutes. During this time the subject was required to lie quietly with muscles relaxed. He was then placed on the ergometer. After riding the man got off quickly and again lay down on the table, this change of position taking about 5 seconds. Subsequently the pulse was counted during the first 15 seconds of each minute until the rate became normal.

At present we are primarily interested in the pulse values recorded with the subject in the lying position prior to the work. The first observations under these conditions were obtained on October 19 and usually followed at 3 or 4 day intervals throughout the rest of the study, excluding the Christmas recess. In considering these pulse-rates it should be borne in mind that they were obtained after a relatively short period of relaxation. The ergometer was in a room on the second floor of the gymnasium. Frequently the subjects ran rather rapidly up the steps to this room, and it is conceivable that the time allowed for the pulse to reach normal, namely 4 to 10 minutes, was hardly long enough. On the other hand, as the increment due to riding was frequently over 100 per cent, the values were sufficiently exact as a base line for Professor Johnson's study.

These pulse values also differ from those previously discussed as the subjects were not in the post-absorptive condition. All observations were taken between the hours of $9^h30^m$ and $11^h30^m$ a. m., and $1^h30^m$ and $4^h30^m$ p. m., *i. e.*, from 2 to 4 hours after the last meal. Under these conditions the pulse-rate was undoubtedly influenced to a certain extent by food ingestion which would tend to increase the values. Since each man usually came for his test at approximately

[1]Some of the electrocardiograms, as previously noted, were not taken under these conditions.

the same hour of the day, the results are more or less comparable with one another.

*Bro*, *Gul*, and *Gar* of Squad A did the work on the ergometer between the hours of $9^h30^m$ and $11^h30^m$ a. m. The rest of the men in Squad A came in the afternoon between $1^h45^m$ and $4^h30^m$ o'clock, nearly always in the following order: *Pec, Vea, Can, Moy, Spe, Mon, Tom, Kon*, and *Pea*. In Squad B, *How, Ham, Wil*, and *Liv* always came between $9^h30^m$ and 11 a. m. The rest of Squad B came between the hours of 2 and $4^h30^m$ p. m., as follows: *Sne, Van, Har, Tho, Lon, Fis, Sch* and *Kim*.

PULSE-RATE, LYING BEFORE WORK, SQUAD A.

The normal pulse-rates of the subjects in Squad A prior to the bicycle-ergometer experiments, as recorded by Professor Johnson, are given in table 84. Unfortunately these interesting values were not obtained during the normal diet period, as the records did not begin until October 19, when the men had already been upon a reduced diet for practically two weeks. The individual values show, however, a striking tendency toward a falling off in pulse-rate, although, as would be expected, relatively few reached 40 or below, hence the number of italicized figures showing this lower level is proportionately reduced and but few figures in bold-face type are to be noted. Emphasis must again be laid upon the fact that these pulse-rates were no doubt influenced by the presence of food in the stomach and previous moderate exercise.

These pulse-rates, however, are the best pulse records we have of the post-diet condition of the men in Squad A. The restricted diet was discontinued on February 3. Professor Johnson made a series of observations 5 days later (February 8), which are perfectly comparable with those made on January 31. All of the men who were available for observation on the later date showed pronounced rises. The greatest increase is that with *Kon*, whose pulse nearly doubled, rising from 45 to 82. The smallest rise was observed with *Gar*, the increase being from 58 to 66. The average rise for the entire squad was from 48 to 71. A still further average increase was noted on February 11, but constant values were obtained for the following 2 days. From February 20 to March 7, inclusive, there is a definite tendency for a slight falling off in pulse-rate from the higher level of February 11, 15, and 18, so that the average for the last 5 days of observation is not far from 68. The isolated instance of a pulse-rate of 89 obtained with *Tom*, which is included in the average, should be called to attention. Undoubtedly 89 is an aberrant figure which should not legitimately be included in the average, but it is used here, as it represents the absolute highest pulse-rate in the table.

While, therefore, strict uniformity could not be maintained in taking the pulse records in table 84 under the conditions previously noted, especially the prior activity and the food in the stomach, never-

TABLE 84.—*Daily pulse-rate with food*[1]—*Squad A subjects in lying position.*

[illegible]

[1] Observations made between 9h30m and 11h30m a. m. and between 1h30m and 4h30m p. m. just prior to work on the bicycle ergometer, constancy having been obtained for several counts.
[2] See table 80, p. 385.
[3] *Kon* was on normal diet on this day, and hence this pulse-rate is not included in the average.

theless the picture is reasonably uniform with practically all subjects, showing an effect of the low diet upon the pulse-rate before work and especially a pronounced increase following the resumption of full diet.

The high value of *Moy* on January 7 has an interest, as it will be remembered that in the discussion of the early morning pulse-rates in table 80 he was shown to be one of two men who, on return from the Christmas vacation, had a pulse-rate lower than the last value recorded in December. The post-absorptive pulse-rate of 43 in table

80 was observed during the early morning experiment of January 8, while the high pulse-rate of 74 was recorded immediately before the work experiment of Professor Johnson on the day preceding (January 7). The records indicate that this man returned to Springfield before dinner on January 7 and was a subject for the work test near the middle of the afternoon. Professor Johnson's pulse records during the experiment show that *Moy's* pulse-rate of 74 prior to work was an average of three countings. Following the work the pulse-rate at the end of 8 minutes was 76 and it finally reached a level of 74 at the end of 9 minutes. These later records seem to verify completely the initial high count. The record of 43 for January 8 in table 80 indicates that the pulse-rate had fallen to a level below his pulse level prior to the Christmas recess. On January 9 the pulse in the early morning was 60. For several weeks subsequent to this date, pulse-rates averaging 42 beats were obtained, with fair agreement between the two series of records.

The same subject (*Moy*) had on November 2 a pulse-rate prior to work of 70 as compared to one of 48 on October 29. Table 80 shows that the pulse-rate of *Moy* in the early morning of November 2 was only 40. We thus have here again a marked difference between the post-absorptive pulse and the pulse-rate prior to work. With the other men, fluctuations as pronounced as this are rarely observed. Attention should, however, be called to the high value of 78 on December 3 with *Tom*. Unfortunately on that particular day there is no post-absorptive pulse value for comparison as his respiratory exchange was not measured that morning; the early morning record for the next day (December 4) was 64.

For further comparison we give in the last column of table 84 the averages obtained for the post-absorptive pulse-rates in the lying position which were recorded in the early morning. (See table 80, p. 385.) Although, of course, the comparison can only be made for the low-diet period, since no early-morning records were made after February 3, these figures show, as would be expected, that the pulse-rate prior to bicycle riding was in all but two cases higher than in the morning. On January 18 and 21, identical values were found both for the pulse in the early morning and for the pulse prior to work, namely, 49 and 44 on the two days, respectively. The difference between the levels of the two series of values may best be observed from the curves for the average normal pulse-rate prior to work and the average basal pulse-rate in the morning given on the chart in figure 91 (p. 411). As indicated by the last two columns of table 84, this difference is usually not far from 3 to 6 beats.

This intimate comparison of these two series of pulse data supplies a logical argument for the scientific recording of pulse-rates only when the subject is in the post-absorptive condition and after a considerable

period of muscular repose. Under these conditions, as may be seen from table 80, striking irregularities are usually avoided and the pulse-rate seems to provide an admirable index of the general metabolic condition.

### PULSE-RATE, LYING BEFORE WORK, SQUAD B.

The absence of pulse observations on Squad A prior to the period of diet restriction is a fault in the pulse study with this squad. With Squad B, excepting when they were on low diet January 8 to 28, inclusive, certain values were obtained which make up in part for this deficiency in normal values with Squad A. Thus, beginning October 24, Professor Johnson obtained lying values for the pulse-rate of these subjects prior to work, and as the squad had no diet restriction until January 8, the values between these two dates supply material for comparison. The pulse values recorded by Professor Johnson are given in table 85 for both the normal, restricted, and unrestricted diet periods. The daily averages are given for these subjects as was done for Squad A.

TABLE 85.—*Daily pulse-rate with food*[1]—*Squad B, subjects in lying position.*

[1] Observations made between 9h30m and 11h30m a. m. and between 11 a. m. and 2 p. m. just prior to work on the bicycle ergometer, constancy having been obtained for several counts.

[2] On March 1 the pulse-rate of *Lon* was 61; of *Kim*, 69.

The pulse-rates of the several men did not vary widely from day to day prior to the period of diet restriction, except in one or two instances, such as with *Har*, whose records varied from 53 to 74. Usually the ranges are within 8 or 14 beats. The average daily rate was 66 for

the first day, when undoubtedly the novelty of the test played some rôle. The subsequent values prior to diet restriction were essentially constant, ranging only from 64 to 60. On January 9, the first observation after the diet was reduced, no great change in pulse-rate was found, save with *Lon* and *Sne*, whose pulse-rate fell 9 beats, a change however, no greater than that observed on previous days with a few subjects. On January 16, however, there was a pronounced fall with practically all of the men save *Ham*, whose pulse-rate of 61 on January 9 and 16 is actually higher than the rate for December 12. The extraordinarily low rates of *Sch* of 38, representing the absolute minimum values found with all the men, except for the isolated figure for *Van* of 37 on January 23, would have been particularly interesting for a comparison with prediet values. Unfortunately no such values were obtained for this subject, as *Sch* did not enter the squad until later in the year. Comparing the average values for the period of restricted diet, we find that although the first record (that for January 9) is the same as the last normal record, *i. e.*, 60 beats, the pulse-rate dropped on January 16 and 23 to 52 and 48, respectively. With the resumption of normal diet the first record (that for January 30) shows a decided increase in pulse-rate in every instance, the most striking being that with *Sne* of 24 beats. The average for the whole squad shows an increase from 48 to 63, or 15 beats per minute. On the next experimental day, February 6, there was a still further increase with all but two men, *Ham*, whose pulse-rate decreased 6 beats, and *Tho*, whose rate did not change. A large increase was noted with *How* from 65 to 92. The average for the squad increased from 63 to 70. On the next two experimental days the average pulse-rate remained essentially the same, but on February 26 and March 6 there was a tendency towards a fall, the average values being 63 and 61, respectively. These later pulse-rates represent values which are probably characteristic of the normal dietetic habits of these subjects.

Thus with Squad B we have a complete duplication of the picture shown with Squad A, except that in this series of records we have also normal values prior to the diet reduction, in addition to the normal values with the resumption of full diet. While the minimum average value with Squad B was 48 as compared with the minimum average value of 44 with Squad A, it is clear that the influence of restricted diet upon the pulse-rate as indicated by both squads was very pronounced.

## PULSE-RATE WITH SITTING POSITION.

### PULSE-RATE WITH SITTING POSITION, PSYCHOLOGICAL TESTS.

All of the pulse data given in the previous section, save those taken by Professor Johnson and certain of the electrocardiograms, were obtained with the subject in the lying position in the post-absorptive condition and without previous activity. Beginning with December 8,

another series of observations was made in connection with the psychological program at the Laboratory. The series consisted of six records which were taken by wrist counts. No. 1 was taken immediately after the adding test, No. 2 immediately after the pitch discrimination, and No. 3 after the clerical test. These the subjects themselves counted. Nos. 4, 5, and 6 were counted by the experimenter, No. 4 after the finger movements, No. 5 after the patellar reflex. No. 6 was taken the following morning, after the finger-movement test; thus, while the values for this last count are entered under a given date, they actually belong to the following day. The data for the six observations are given in table 86 for Squad A and in table 87 for Squad B.

TABLE 86.—*Pulse data taken in connection with psychological sessions—Squad A, subjects sitting.*

[1] Taken on morning following date given.
[2] Electrocardiograms taken; no wrist counts made.
[3] Walking experiment in place of psychological measurements.

TABLE 87.—*Pulse data taken in connection with psychological sessions—Squad B, subjects sitting.*

[illegible]

[1] Taken on morning following date given.
[2] Walking experiment in place of psychological measurements.

On the morning of December 20 arrangements were made for taking electrocardiograms of the men; hence the morning pulse-rate (No. 6 for December 19) was omitted. On the morning of February 3 with Squad A and of January 6 and 28 with Squad B the walking experiments on the treadmill were made; hence no pulse counts appear in the tables for No. 6 on February 2 and January 5 and 27. On all other days, six records were made. Although the pulse-rate for the sitting position would be expected to be somewhat higher than that for the

lying position, we have adhered to the procedure followed in table 80 of italicizing all pulse values between 40 and 36, inclusive, and giving in bold-face type the occasional records which are 35 or below. In interpreting the results of these pulse records in table 86 it should be borne in mind that all values were taken subsequent to the ingestion of food. As may be seen from the program for the day (see p. 59), the first count was approximately an hour after the standard restaurant supper eaten by the men on their visit to Boston. Counts Nos. 1 and 2 were made simultaneously by the entire squad. Counts Nos. 3, 4, 5, and 6 varied somewhat in time, as they were recorded in the intermission of the individual psychological tests which were given to the men in order during the evening and again on the following morning. Even with this variation in time, none of the subjects were in the post-absorptive condition and the influence of food ingestion as well as that of the sitting position must be recognized in comparing these pulse values with other series.

Noting first the course of the pulse values obtained by the subjects themselves in the first three counts of each evening, we find that the first count for Squad A (that for December 8) was made when the subjects had been for several weeks on reduced diet. On February 2 the pulse-rate was in most instances somewhat higher than on the other days, and the men were evidently more or less stimulated by the fact that this was the last session.

The pulse-rates on December 19 and January 12 and 26 were reasonably uniform, although the values for January 12 have a tendency to be higher than on either of the other days. No basal pulse counts were obtained under these conditions, either prior to the low diet or after normal diet was resumed. Values between 40 and 36 occur with 6 subjects and values of 35 or below with 3 subjects. The absolute minimum was observed with *Vea*, in count No. 5 on the evening of January 26, with a low value of 33. In general the pulse had a tendency to fall off as the evening progressed, the highest value appearing in count No. 1 and the lowest usually in count No. 5. The count taken the following morning usually shows values higher than the last count in the preceding evening. Only 2 pulse-rates of 40 appear in the No. 6 values. The difference between Nos. 5 and 6, or the last record of the evening and the first record of the morning, is, in the case of *Bro*, very slight. With the other subjects it is pronounced, showing on the whole a real difference in metabolic level. This may in part be ascribed to the fact that the pulse records in the morning were usually taken not long after breakfast and following the incidental activity of rising, leaving the respiration chamber, walking up a flight of stairs, dressing, eating breakfast, and going downstairs to the psychological laboratory, an activity which was as a rule considerably more marked than that preceding the counts on the evening before.

With Squad B we have certain values for comparison which may be taken as normal, *i. e.*, those for December 15 and January 5. In table 87 we have again adopted the arbitrary procedure of italicizing all values of 40 and below. The lowest absolute value found in any instance is 37 with *Liv* on the evening of January 27. Most of the italicized figures fall in count No. 5, a condition likewise observed in the case of Squad A.

In general, the normal values found on January 5 or prior thereto are not greatly altered on January 13 (the first session with reduced diet); the only striking exceptions to this uniformity are with *How* and *Sch*. It would thus appear that one week of reduced diet was not sufficient to affect greatly the pulse values for this squad when taken with the men in the sitting position and undergoing the moderate intellectual and physical activity of the psychological tests. On the other hand, an examination of all the data for January 19 and 27 shows almost invariably marked decreases in pulse-rate for all the counts. Thus we have a clear picture during the last two sessions of a decided influence of the reduced diet upon the sitting pulse taken under conditions of the psychological session at the Nutrition Laboratory.

Although as a rule the values in column 6 are greater than those in column 5, too many irregularities exist to permit of any definite deduction being drawn. The pronounced influence of the reduced diet shown in table 87, especially after the first week, is in complete harmony with the effect noted in tables 80 to 82 upon the resting pulse-rate taken with the men in both squads in the lying position. These sitting pulse-rates, which were influenced more or less by minor activity and particularly by food in the stomach, have by no means the significance of the basal morning pulse, but they serve to show that not only is the quiescent resting pulse profoundly affected by the dietetic règime, but that the sitting pulse following digestion is likewise affected. The fact that with Squad B this influence is hardly appreciable at the end of the first week of dieting is of significance when it is considered that these men were upon a diet representing approximately but one-third of their previous maintenance requirements. Pulse data of this character are especially helpful in suggesting the probability that the total heart action and metabolism are profoundly depressed by the low diet, not only during periods of complete muscular repose, but likewise under conditions of moderate intellectual and physical activity, complicated in part by digestive processes, although, owing to the extraordinarily reduced diet, it is hardly to be presumed that the influence of the ingestion of food is at all comparable to that existing under normal conditions.

### PULSE RECORDS AT MEAL TIMES.

Through the kindness of Mr. Charles Wesley Davis, of the Y. M. C. A. College, we are permitted to use some pulse-rate data obtained

under his direction at the noon and evening meals with Squad A and with all three meals with Squad B. For this series of observations each man was instructed to count his own pulse once during the meal and record it on a tablet on the table. The counts were made from October 17 to the end of the research.

### Pulse Records at Meal Times, Squad A.

As an indication of the ordinary course of the pulse-rate counted under these conditions at the noon meal, we reproduce in table 88 a

Table 88.—*Individual pulse records at noon meal—Squad A.*

| | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pea. | Pec. | Spe. | Tom. | Vea. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 17 | ..... | 64 | ..... | 54 | 72 | 66 | 80 | 50 | 70 | 66 | 92 | 86 | 70 |
| 18 | ..... | 70 | [1]70 | 70 | 68 | 64 | 52 | 48 | 56 | 64 | 80 | 68 | 65 |
| 19 | 76 | 56 | [1]70 | 52 | 70 | 70 | 62 | 50 | 84 | 82 | 70 | 56 | 67 |
| 20 | ..... | 50 | [1]58 | 54 | 64 | 60 | 54 | 48 | 58 | 54 | 84 | 56 | 58 |
| 21 | 76 | 64 | [1]68 | 56 | 84 | 62 | 58 | 60 | 50 | 74 | 88 | 84 | 69 |
| 22 | 70 | 66 | [1]64 | 68 | 66 | 64 | 52 | 48 | 42 | 64 | 72 | 48 | 60 |
| 23 | 70 | 56 | ..... | 48 | 66 | 66 | 48 | 46 | 60 | 58 | 68 | 52 | 58 |
| 24 | ..... | 70 | [1]60 | 64 | 72 | 66 | 68 | 46 | 54 | 64 | 74 | 56 | 63 |
| 25 | ..... | 54 | [1]64 | 48 | 72 | 64 | 52 | 46 | 48 | 62 | 68 | 48 | 57 |
| 26 | 80 | 60 | ..... | 48 | 72 | 62 | 54 | 50 | 54 | 80 | 72 | 56 | 63 |
| 27 | ..... | 56 | ..... | 46 | 68 | 66 | 50 | 58 | 70 | 74 | 84 | 60 | 63 |
| 29[2] | ..... | 56 | ..... | 50 | ..... | 64 | ..... | ..... | 48 | ..... | ..... | 52 | 54 |
| 30 | ..... | ..... | 60 | 64 | 72 | 72 | 64 | 50 | 58 | 76 | 72 | 56 | 64 |
| 31 | 60 | 56 | 48 | 52 | 68 | 60 | 58 | 56 | 52 | 56 | 66 | 60 | 58 |
| Nov. 1 | ..... | 62 | 54 | 64 | 72 | 60 | 50 | 42 | 48 | 60 | 66 | 56 | 58 |
| 2 | 84 | 46 | 54 | 48 | 66 | 62 | 62 | 48 | 46 | 66 | 68 | 56 | 59 |
| 3 | 56 | 54 | ..... | 52 | 72 | 66 | 60 | 48 | 50 | 52 | 60 | 60 | 57 |
| 4 | 56 | 56 | 54 | 52 | 66 | 62 | 52 | 42 | 56 | 52 | 68 | 56 | 56 |
| 5 | 72 | 68 | 50 | 64 | 62 | 64 | 48 | 44 | 58 | 62 | 60 | 60 | 59 |
| 6 | 62 | 58 | 58 | 60 | 52 | 68 | 50 | 44 | 50 | 68 | 54 | 68 | 58 |
| 7 | 52 | ..... | 56 | 64 | 62 | 68 | 42 | 50 | 48 | 58 | ..... | 60 | 56 |
| 8 | 54 | 52 | 50 | 46 | 54 | 58 | 40 | 46 | 40 | 54 | 68 | 48 | 51 |
| 9 | 58 | 54 | 54 | 56 | ..... | 54 | 42 | 52 | 38 | 50 | 76 | 40 | 52 |
| 10 | 78 | 50 | 50 | 52 | 60 | 56 | 48 | ..... | 54 | 54 | 68 | 52 | 57 |
| 12[3] | 56 | 56 | 44 | 44 | 58 | 54 | 48 | 50 | 48 | 52 | ..... | 56 | 51 |
| 13 | 56 | 54 | 44 | 52 | 64 | 56 | 48 | 50 | 40 | 56 | 76 | 44 | 53 |
| 14 | 52 | 54 | 46 | 58 | 58 | 66 | 44 | 56 | 50 | 72 | 68 | 48 | 56 |
| 15 | 60 | 66 | 46 | 46 | 64 | 60 | 42 | 44 | 50 | 60 | 72 | 48 | 55 |
| 16 | 64 | 50 | 44 | 42 | 62 | 60 | 56 | 46 | 40 | 78 | 64 | 44 | 54 |
| 17 | ..... | 56 | 46 | 50 | 66 | 66 | 52 | ..... | 42 | 98 | ..... | 52 | 59 |
| 18 | 72 | 58 | 56 | 44 | 66 | 60 | 40 | 48 | 46 | 70 | 64 | 48 | 56 |
| 19 | 56 | 52 | 46 | 52 | 58 | 60 | 44 | 46 | 36 | 72 | 68 | 48 | 53 |
| 20 | 52 | 52 | 44 | 44 | 62 | 60 | 46 | 46 | 44 | 56 | 60 | 40 | 51 |
| 21 | 58 | 50 | 40 | 52 | 64 | 54 | 42 | 50 | 34 | 54 | 56 | 40 | 50 |
| 22 | ..... | 62 | 40 | 42 | 54 | 50 | 36 | 42 | 36 | 54 | 70 | 48 | 49 |
| 23 | 52 | 56 | 40 | 52 | 50 | 60 | 44 | 48 | 38 | 58 | 72 | 48 | 52 |
| 24 | 60 | 62 | 38 | 40 | 52 | 66 | 34 | 38 | 34 | 54 | 48 | 40 | 47 |
| 26[4] | 68 | 62 | 42 | ([5]) | 76 | 60 | 44 | 52 | 48 | 76 | ..... | 52 | 58 |
| 27 | 68 | 62 | 40 | ([5]) | 64 | 62 | 40 | 42 | 44 | 60 | 64 | 48 | 54 |
| 28 | ..... | ..... | 52 | 56 | 60 | 66 | 60 | 62 | 46 | 72 | ..... | 48 | 58 |
| 29[6] | 46 | 56 | 56 | ..... | ..... | 64 | 46 | 46 | 62 | 60 | 88 | 52 | 58 |
| 30 | ..... | 56 | 56 | 44 | 56 | 62 | 56 | 46 | 60 | 56 | 80 | 44 | 56 |

[1] These records were obtained with *Fre* who left Squad A on Oct. 25.
[2] In Boston Oct. 28; no record taken.
[3] In Boston Nov. 11; no record taken.
[4] In Boston Nov. 25; no record taken.
[5] Ill with a cold.
[6] Thanksgiving Day; the men had full diet.

TABLE 90.—*Individual pulse records at evening meal—Squad A.*

| | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pea. | Pec. | Spe. | Tom. | Vea. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 17.... | ..... | 58 | ..... | 60 | ..... | ..... | ..... | 72 | 72 | 68 | ..... | 72 | 67 |
| 18.... | ..... | 52 | [1]64 | 60 | ..... | 74 | 58 | 58 | ..... | 74 | 75 | 52 | 63 |
| 19.... | ..... | 70 | [1]76 | 50 | 78 | 66 | 68 | 50 | 72 | 70 | 76 | 62 | 67 |
| 20.... | 86 | 70 | [1]62 | 60 | 72 | 60 | 66 | 68 | 60 | 70 | 92 | 60 | 69 |
| 22.... | ..... | 64 | [1]78 | 50 | 70 | 66 | 56 | 46 | 64 | 64 | ..... | 60 | 62 |
| 23.... | 76 | 62 | [1]80 | 54 | 66 | 66 | 54 | 54 | 48 | 82 | 74 | 56 | 64 |
| 24.... | ..... | 60 | [1]74 | 48 | 70 | 68 | 50 | 50 | 56 | 76 | 72 | 60 | 62 |
| 25.... | ..... | ..... | [1]72 | 56 | 78 | 64 | 58 | 54 | 56 | 70 | 62 | 48 | 62 |
| 26.... | ..... | 68 | ..... | 46 | 74 | 62 | 68 | 56 | 64 | 92 | 74 | 56 | 66 |
| 27.... | 70 | 56 | 64 | 46 | 68 | 70 | 60 | 52 | 54 | 76 | 72 | 72 | 63 |
| 29[2].... | 80 | 66 | ..... | 60 | ..... | 66 | 52 | 56 | 56 | 66 | 86 | 68 | 66 |
| 30.... | 76 | 68 | 54 | 44 | 72 | 56 | 68 | 48 | 48 | 60 | 66 | 56 | 60 |
| 31.... | 84 | 46 | 76 | 48 | 78 | 66 | 56 | 60 | 52 | 80 | 82 | 60 | 66 |
| Nov. 1.... | ..... | 56 | 70 | 64 | 78 | 80 | 82 | 46 | 52 | 60 | 64 | 56 | 64 |
| 2.... | ..... | 50 | 54 | 50 | 72 | 52 | 60 | 50 | 46 | 74 | 80 | 60 | 59 |
| 3.... | 66 | 56 | ..... | 54 | 58 | 56 | 46 | 56 | 58 | 52 | 60 | 48 | 55 |
| 5.... | 72 | 60 | 64 | 50 | 66 | 60 | *40* | 46 | 50 | 68 | 60 | 64 | 58 |
| 6.... | 72 | 54 | 54 | 56 | 60 | 80 | 44 | *40* | 50 | 62 | 60 | 60 | 58 |
| 7.... | 60 | 50 | 58 | 50 | 72 | 64 | 50 | 62 | 58 | 58 | 72 | 48 | 59 |
| 8.... | ..... | 58 | 62 | 52 | 46 | 50 | 44 | *40* | 50 | 68 | 64 | 44 | 53 |
| 9.... | 64 | 64 | 48 | 50 | ..... | 56 | 58 | 48 | ..... | 60 | 76 | 52 | 58 |
| 10.... | 72 | 64 | 68 | 48 | 60 | 58 | 48 | 52 | 52 | 64 | 72 | 52 | 59 |
| 12[3].... | 60 | 60 | 44 | 58 | 54 | 48 | 66 | 46 | 64 | 74 | 72 | 60 | 59 |
| 13.... | 58 | 58 | 48 | 46 | 60 | 56 | 44 | 48 | 48 | 70 | 64 | 48 | 54 |
| 14.... | 64 | 70 | 70 | 48 | 62 | 82 | 50 | 60 | 54 | 68 | 72 | 52 | 63 |
| 15.... | 72 | 72 | 50 | 56 | 52 | 60 | 60 | 50 | 76 | 52 | 72 | 48 | 60 |
| 16.... | 82 | 56 | 44 | 50 | 66 | 58 | 56 | 44 | 46 | 80 | 64 | *40* | 57 |
| 17.... | 64 | 60 | 48 | 42 | 60 | 52 | 46 | 56 | 46 | 90 | 64 | 48 | 56 |
| 19.... | 60 | 58 | 46 | 50 | 60 | 70 | 42 | 48 | 50 | 66 | 64 | 52 | 56 |
| 20.... | 62 | 50 | 68 | 52 | 62 | 66 | *40* | 48 | 46 | 76 | 68 | 44 | 57 |
| 21.... | ..... | 62 | 46 | 48 | 68 | 64 | ..... | 50 | 54 | 60 | ..... | 44 | 55 |
| 22.... | ..... | 54 | 46 | 50 | 68 | 66 | ..... | 50 | ..... | 80 | 76 | 48 | 60 |
| 23.... | 70 | 54 | *40* | 52 | 62 | 64 | 46 | 50 | 42 | 54 | ..... | 48 | 53 |
| 24.... | 78 | 66 | 44 | 46 | 48 | 64 | 46 | *40* | 34 | 56 | 64 | 48 | 53 |
| 26[4].... | 78 | 66 | ..... | ..... | 76 | 74 | 48 | 58 | 42 | 70 | 76 | 44 | 63 |
| 27.... | 72 | ..... | 44 | ..... | 64 | 70 | 52 | 48 | 44 | 74 | ..... | 48 | 57 |
| 29[5].... | 76 | 70 | 70 | 58 | 76 | 64 | 64 | 56 | 56 | 80 | [6]104 | 56 | 69 |
| 30.... | ..... | 52 | 52 | 50 | 72 | 62 | 68 | 44 | 42 | 54 | 80 | 48 | 57 |

[1] These records were obtained with *Fre* who left Squad A on Oct. 25.
[2] In Boston Oct. 28; no record taken.
[3] In Boston Nov. 11; no record taken.
[4] In Boston Nov. 25; no record taken.
[5] Thanksgiving Day; the men had full diet. No record for Nov. 28.
[6] Highest individual rate during entire test with Squad A.

in which the daily averages are likewise given at the extreme right. Here again a tendency is shown for the pulse-rate to fall as the study progressed, the absolute minimum for the entire squad (53 beats) being noted on three days, November 8, 23, and 24. An unusually high value was obtained on November 29, which was due in no small part to the extraordinarily high pulse-rate of *Tom* of 104, which was recorded as the highest individual pulse-rate noted for Squad A.

The averages for the successive periods of the observations for the evening meals are given in table 91 and show little, if any, positive change due to the diet. The level after the first period in table 91

TABLE 91.—*Average pulse records at evening meal—Squad A.*

| Subject. | Oct. 17 to 31. | Nov. 1 to 15. | Nov. 16 to 30. | Dec. 5 to 19. | Jan. 7 to 20. | Jan. 21 to Feb. 2. |
|---|---|---|---|---|---|---|
| Bro.......... | 79 | 66 | 71 | 68 | 74 | 73 |
| Can.......... | 62 | 59 | 59 | 60 | 63 | 62 |
| Kon.......... | 65 | 58 | 50 | 51 | 59 | 44 |
| Gar.......... | 53 | 49 | 50 | 50 | 61 | 53 |
| Gul.......... | 73 | 62 | 65 | 62 | 69 | 60 |
| Mon.......... | 65 | 62 | 65 | 67 | 71 | 69 |
| Moy.......... | 60 | 53 | 51 | 52 | 60 | 56 |
| Pea.......... | 56 | 50 | 49 | 49 | 57 | 49 |
| Pec.......... | 59 | 55 | 46 | 50 | 57 | 52 |
| Spe.......... | 73 | 64 | 70 | 71 | ........ | .......... |
| Tom.......... | 76 | 68 | 74 | 70 | 85 | 73 |
| Vea.......... | 60 | 53 | 47 | 45 | 47 | 43 |
| Average.. | 65 | 58 | 58 | 58 | 64 | 58 |

remains remarkably constant at 58. From January 7 to 20 this level rises to 64, but again falls to 58 in the last period of the observations. From tables 89 and 91, therefore, while something can be inferred regarding the influence of reduced diet upon the pulse-rate, evidently averages obtained in this way for long periods will not suffice for a clear analysis, and a better idea may be obtained from a graphic representation of the individual values. Such representation is given in figure 91, (p. 411) in which the curves for the lying and sitting values obtained with Squad A are compared with each other.

PULSE RECORDS AT MEAL TIMES, SQUAD B.

The pulse data taken at meal times for Squad B in this series have a significance not found with those for Squad A, as with the second squad the counts were made with both normal and low diet. It is unnecessary here to give in detail the individual measurements reported by Mr. Davis, but the differences between the pulse values during October, November, and December and those for the January period have a special interest, as those for the first three months were obtained under normal diet conditions, while most of those recorded in January were with the low diet. With Squad B pulse counts were made not only at the noon and night meals, but likewise during the morning meals, and hence a direct comparison may be made of the morning, noon and night values. This comparison is made in table 92. Inasmuch as the subjects were on normal diet until January 8, we find a reasonable uniformity in the values. The normal morning pulse-rate averaged 63, the noon pulse 72, and the night 68. With the beginning of the reduced diet, however, a noticeable fall in the pulse-rate is found with the entire group, and the three average values recorded beginning January 8 are on a definitely lower level than any of the earlier records. The average for the morning records during the low-diet period from January 8 to

TABLE 92.—*Average pulse records at morning, noon, and evening meals—Squad B.*[1]

| | Morning. | Noon. | Night. | | Morning. | Noon. | Night. |
|---|---|---|---|---|---|---|---|
| Oct. 19 to 31 | 63 | 73 | 66 | Jan. 1 to 7 | 62 | 70 | 66 |
| Nov. 1 to 15 | 63 | 74 | 68 | Jan. 8 to 12 | [3]59 | [3]65 | [3]61 |
| Nov. 16 to 30 | 63 | 72 | 68 | Jan. 13 to 20 | [3]57 | [3]62 | [3]57 |
| Dec. 1 to 12 | 63 | 70 | 68 | Jan. 21 to 28 | [3]53 | [3]57 | [3]55 |
| Dec. 13 to 19 | 63 | 70 | 69 | Jan. 29 to Feb. 2[4] | 64 | 70 | 72 |
| Dec. 20 to 31[2] | 63 | 72 | 70 | | | | |

[1] Only 8 men included in these averages.
[2] Records for only four men.
[3] With reduced diet.
[4] Records for only two men; unrestricted diet.

28 was 56 beats, or 7 beats lower than with full diet. The noon average with reduced diet was 61 beats, or 11 beats lower than with the normal diet. At night the rate was lower than at noon, being 68 on normal diet and 58 on restricted diet with a difference of 10 beats. With Squad A the reverse was found, the evening rate being higher than that recorded at noon. This may in part be explained by the fact that the members of Squad A took their physical exercise between $3^h30^m$ and 5 o'clock in the afternoon while most of the men in Squad B took theirs in the morning; hence the after-effect of muscular activity may have influenced the pulse-rates.

In the post-diet period we have observations for but two men. These show the characteristic rise in pulse-rate which is likewise observed with Squad A in the post-diet values obtained prior to bicycle riding. (See p. 397.) The general picture, therefore, presented by Squad B is in full conformity with that shown by Squad A and in addition we have a very clear picture of the normality of the pulse-rate taken under conditions obtaining in Mr. Davis's counts.

While these sitting pulse-rates of Squads A and B counted by the subjects themselves under considerable psychical, digestive, and slight muscular activity can not have the significance of careful records during complete repose, they contribute important confirmatory evidence as to the depressing effect of the reduced diet upon the heart rate.

## PULSE CURVES FOR SQUAD A.

To give an indication of the general influence of the reduced diet upon the pulse-rate of the men in Squad A as observed in the series discussed in the previous sections, we have plotted the average values and give these curves in figure 91. The values plotted include: (1) the averages obtained for the basal pulse in the early morning, with the subject in the post-absorptive condition, without previous activity, and in the lying position; (2) the averages secured by Professor Johnson immediately before work with the subject in the lying position but not in the post-absorptive condition; (3) those obtained by the subjects on themselves in the sitting position at the noon meal, and (4) in the same position at the evening meal.

## PULSE-RATE WITH STANDING POSITION.

### STANDING PULSE RECORDS IN EXPERIMENTS WITH PORTABLE RESPIRATION APPARATUS.

Any records of pulse-rate taken under uniform conditions in a given position are of value as evidence of the influence of reduced diet upon this factor. A number of respiration experiments were made with these men which were designed primarily to determine the basal metabolism with the subject in the standing position prior to a series of measurements of the energy transformations during walking. This led to the recording of a number of pulse-rates during this position with both squads. With Squad A these were recorded only on the last day of the observation, that is, on a restricted diet. With Squad B records were obtained on January 6 before the subjects had begun the low diet, and again on January 28, the last day of the greatly reduced diet. These pulse-rates are given for both squads in table 93.

On all these mornings the resting pulse was determined with the subject lying with minimum muscular activity in the group chamber before he rose. These values are also given for all the subjects in column *a* in table 93, for comparison with the standing pulse-rates. The figures, so far as Squad A is concerned, present no abnormalities and show low values similar to those noted on the respiration apparatus at Springfield on the two days preceding. (See table 80.) Values below 40 are found with 5 subjects in each squad.

The pulse measurements for the standing position in the experiments with the portable respiration apparatus, which in some cases were made several hours after the pulse measurements in the group chamber, are given in column *b* of table 93 and show increments for all of the subjects. The increments of the standing pulse over the lying pulse are given in column *c*. The greatest increment for Squad A is with *Can*, whose pulse rose from 48 to 84, *i. e.*, 36 beats. The smallest increments were noted with *Bro* and *Mon*, of 5 each. The average increment is 17, if we exclude the large increment of *Can* in averaging.

It is unnecessary for us to go to earlier literature for a base line or for comparisons, as data were obtained with Squad B on normal and on reduced diet and in both positions. These values are given in the lower part of table 93. Attention may first be called to the fact that the pulse-rates for January 28 were invariably lower than those for January 6, when the men were on normal diet. Especial emphasis must be laid upon the increments due to standing, which are recorded in column *c* of table 93. The highest increment on normal diet is with *Sne*, with an increment of 41 beats, *i. e.*, a rise from 48 to 89 beats. If we exclude this high value for *Sne* the average increment for Squad B with normal diet on January 6 would be 18. It thus appears that the increment due to change from the lying to the standing position was essentially the same on the reduced diet with Squad A as with that on

TABLE 93.—*Comparison of pulse-rates of subjects in lying and standing positions, subjects without food from 11 to 19 hours.*[1]

| Diet and dates. | Squad and subject. | (*a*) Lying in group respiration chamber. | (*b*) Standing at portable respiration apparatus. | (*c*) Increase over lying (*b*-*a*). | (*d*) Standing before walking. | Remarks. |
|---|---|---|---|---|---|---|
| Reduced: | *Squad A.* | | | | | |
| Feb. 3, 1918. | Bro...... | 56 | 61 | 5 | 66 | Pulse-rates lying taken between 4 and 5 a. m., except for Bro, Kon, and Mon, whose records were obtained as late as 6 a. m. |
| | Can...... | 48 | 84 | [2]36 | [3]74 | |
| | Kon...... | 39 | 56 | 17 | ........ | |
| | Gar...... | 36 | 46 | 10 | 44 | |
| | Gul...... | 48 | 73 | 25 | 69 | |
| | Mon...... | 55 | 60 | 5 | 58 | |
| | Moy...... | 45 | 60 | 15 | ........ | |
| | Pea...... | 38 | 59 | 21 | ........ | |
| | Pec...... | 37 | 59 | 22 | 54 | |
| | Tom...... | 60 | 88 | 28 | 80 | |
| | Vea...... | 35 | 54 | 19 | ........ | |
| Average... | .......... | 45 | 64 | [2]17 | 64 | |
| Normal: | *Squad B.* | | | | | |
| Jan. 6, 1918[4]. | Fis...... | 56 | 74 | 18 | 82 | Pulse-rates lying taken between 4 and 5 a. m. |
| | Har...... | 60 | 78 | 18 | 79 | |
| | How...... | 58 | ........ | ........ | 77 | |
| | Ham...... | 63 | 80 | 17 | 95 | |
| | Kim...... | 59 | 83 | 24 | 80 | |
| | Sch...... | 45 | 69 | 24 | 68 | |
| | Liv...... | 60 | 68 | 8 | 71 | |
| | Sne...... | 48 | 89 | [2]41 | 69 | |
| | Tho...... | 54 | 71 | 17 | 77 | |
| | Van...... | 54 | 72 | 18 | ........ | |
| | Wil...... | 57 | 72 | 15 | 83 | |
| Average... | .......... | 56 | 76 | [2]18 | 78 | |
| Reduced: | *Squad B.* | | | | | |
| Jan. 28, 1918[5] | Fis...... | 39 | 66 | 27 | 55 | Pulse-rates lying taken about $4^h30^m$ a. m. |
| | Har...... | 44 | 65 | 21 | ........ | |
| | How...... | 40 | ........ | ........ | ........ | |
| | Ham...... | 42 | 67 | 25 | 55 | |
| | Kim...... | 48 | 71 | 23 | 60 | |
| | Sch...... | 33 | 51 | 18 | ........ | |
| | Liv...... | 39 | 53 | 14 | 43 | |
| | Sne...... | 40 | 71 | [2]31 | [3]67 | |
| | Tho...... | 39 | 55 | 16 | 51 | |
| | Van...... | 34 | 50 | 16 | 46 | |
| | Wil...... | 47 | 56 | 9 | ........ | |
| Average... | .......... | 40 | 61 | [2]19 | 54 | |

[1] The time when the pulse was observed for the standing position varied according to the order in which subjects were used.

[2] Increase over lying for *Can* and *Sne* omitted from averages.

[3] The value of 74 for *Can* is an average of 81 (standing outside chamber) and 67 (standing on treadmill in chamber); likewise 67 for *Sne* is an average of 72 and 62.

[4] *McM*, Jan. 6; pulse-rate, lying, 63; standing at portable, 80; increase over lying, 17; standing before walking, 84.

[5] *Lon*, Jan. 28; pulse-rate, lying, 35; standing at portable, 52; increase over lying, 17.

the subjects in the low-diet research began somewhat early to exhibit radial pulse-rates which were notably below those of normal, it appeared to us particularly important to examine the change in heart rate with exertion. An accurate and at the same time the most convenient method of securing records which will provide information of this sort is to take electrocardiograms by the technique described on page 152, *i. e.*, with body electrodes connecting the subject to the string galvanometer for the taking of continuous records while he is quiet, active, and again at rest. The sample records, which are illustrated in figure 24 (see page 152), demonstrate clearly that any considerable irregularity in the rhythm or conduction of the electrocardiogram under these conditions could be readily discovered, except perhaps during the actual moments of exertion, when only the prominent R deflection is legible in the tracing. The auricular wave P is usually very small, partly because of the capacity and resistance in series in the circuit reducing the amplitude of the deflections. The P wave is, however, usually indicated in the quiet pulse prior to exertion. It also becomes visible in the latter part of the recuperation period, and since the ventricular complex (R and T waves) appears with increased frequency between the two points in the record where the P wave is not evident, it is probable that all of the impulses are of sinus origin and proceed in the normal way. No stress can be laid upon the shape of the waves. Only their order and frequency concern us here.

To secure an accurate measure of the length of the pulse cycle, we measured from the sharp point R to R.[1] A table for all the pulse-cycle data shown n these records would be very large and unwieldy. Data of this character for a series of similar electrocardiograms taken on one subject have been published elsewhere.[2] Each individual pulse cycle (R to R distance) is measured, the unit being 0.01 second. In discussing such pulse changes, it is more logical to use pulse-cycle length than pulse-rate per minute. The two statements must not be confused. The data can be conveniently presented in the form of curves. An illustrative set of curves for an individual subject is given in figure 92. Records were taken for *Mon* on the five days, October 28, November 11, December 9, January 13, and January 27. In order to avoid a confused diagram, curves for only three dates are given, those for November 11, December 9, and January 27. In each case the curve is the average for two similar and consecutive records, separated by one minute or more of rest. The portion of the curve to the left of the heavy vertical line represents the period of quiet rest in the steamer chair. The pulse-cycle length varies somewhat, as is to be expected in any normal individual, due to the respiratory changes and other influences on the vagus. No signal or indication was given to the subject

[1] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 95.
[2] Miles, *ibid.*, p. 98, table 17.

until the exact moment when he was to grasp the bar and "chin" himself, the beginning of which event is represented by the vertical heavy line. Immediately at the beginning of exercise the cycle length is shortened and continues to decrease during the 5 seconds of muscular tension, the end of which is indicated in each curve by a short vertical line.

The curve for December 9 in figure 92 is at a higher level—*i. e.*, a faster pu se-rate—particularly in the period of quiet and of rest. It is also to be observed in the case of this curve that at the end of the exertion the pulse continues to rise during about 5 cycles, after which it shows

FIG. 92.—Changes in the pulse-cycle duration with exertion, Kirk G. Montague.

The portion of the curves to the left of the heavy vertical line represents the pulse cycles during quiet. Between the heavy vertical line and the short lines through the curves is the period of exertion. The portion at the right of the short verticals is for the period of recuperation.

a steep decline. December 9 was not long after the Thanksgiving vacation, and the pulse-rate had risen on this date to more nearly its normal level. On November 11 and January 27 the reduced diet had been in force for several weeks continuously in each case and the pulse was at a lower level. The difference in level between December 9 and the other two dates is particularly prominent in the quiet pulse, that is, preceding the activity. It is less prominent in the rest pulse following the activity and rather slight during the activity. It is significant that the cycle length during exercise is so nearly the same, even though the resting pulse is at rather widely different levels. It would appear that

in the case of this individual the given amount of exercise required a pulse-rate of about a certain level, and that in the case of the lower resting rate the tone of the vagus is higher or is somewhat more affected at the time of the exercise.

Different subjects show, naturally, individual peculiarities in their curves for changes in pulse-cycle length during and following the short periods of exertion but, in general, the pulse-cycle length required for the exercise tends with any individual to be a constant, no matter what the resting level may be.[1]

It is rather difficult to place the data for these pulse changes in quantitative terms for comparison. An effort in this direction is made in tables 94 and 95 for Squads A and B, respectively. The three figures given for any subject and date represent the average pulse-cycle length in 0.01 second in the three different portions of the record. For example, with *Bro* on October 28, 0.92″ is the average pulse-cycle length of the 6 pulse cycles in the portion of the record which preceded the beginning of activity, 0.66″ is the average for all of the pulse cycles which came within the limits of the activity, and 0.67″ the average of the 20 pulse cycles which followed the cessation of activity. (See table 94.) With each subject these same conditions for the averages apply. All the members of Squad A, excluding *Kon* and *Spe*,[2] show averages for October 28 of 103 for the period of quiet, 75 for the period of activity, and 79 for the first 20 pulse cycles in recuperation following activity. Assuming the duration of pulse cycles during "quiet" as a basis for calculation, we have for activity and rest 72.8 and 76.6 per cent, respectively, as shown in the extreme right-hand column of the table. Therefore the average cycle-length during the period of activity was 27.2 per cent shorter than during the quiet, and in the 20 beats following the activity it was still on the average 23.4 per cent shorter than during the period of quiet.[3]

The low diet average for Squad A for the 5 dates, October 28, November 11, December 9, January 13, and January 27, and for the 10 men whose records were averaged (*Kon* and *Spe* omitted) are 109, 77, and 85 for quiet, activity, and rest, respectively. The activity and rest are but 70.6 and 78.0 per cent of the quiet pulse-cycle length. The individual subjects show an average pulse-cycle length under conditions of quiet which ranges from 87 to 125—*Tom* and *Pea*. Two other subjects, *Vea* and *Pec*, are very close to this upper value; that is, they

[1] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 102 ff.; see figs. 12, 13, and 14. This was found to be the case, also, when a subject was under the influence of small amounts of alcohol.

[2] *Kon* came into Squad A late and *Spe* was ill after December. These two subjects were omitted from the averages in the neuro-muscular measurements. See p. 557.

[3] While a shorter pulse-cycle length means a faster rate per minute, the quantitative statement for change in the one can not be directly transferred to the other. The average cycle lengths, 103, 75, and 79, in terms of rate would equal 58, 80, and 76, respectively. The activity and rest sections therefore show increments of 22 and 18 beats per minute over the quiet, which was 58. These changes in terms of rate are 38 and 31 per cent as compared to the 27.2 and 23.4 per cent for changes in cycle length.

TABLE 94.—*Different levels of pulse-cycle length with conditions of quiet, activity, and rest for the men of Squad A.*

[Values in 0.01 second for pulse-cycle length.]

| Experiment and condition. | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pea. | Pec. | Spe. | Tom. | Vea. | Av. | P.ct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 28 Quiet.... | 92 | 112 | 109 | 113 | 79 | 97 | 103 | 137 | 100 | 91 | 83 | 109 | 103 | 100 |
| Active... | 66 | 94 | 93 | 69 | 60 | 65 | 76 | 93 | 82 | 67 | 67 | 81 | 75 | 72.8 |
| Rest.... | 67 | 78 | 91 | 70 | 67 | 85 | 84 | 98 | 87 | 65 | 68 | 82 | 79 | 76.6 |
| Nov. 11 Quiet.... | 96 | 104 | 126 | 121 | 73 | 99 | 133 | 136 | 150 | 112 | 90 | 117 | 112 | 100 |
| Active... | 69 | 70 | 76 | 71 | 66 | 70 | 90 | 93 | 86 | 69 | 64 | 100 | 78 | 69.6 |
| Rest..... | 72 | 80 | 79 | 74 | 73 | 80 | 95 | 108 | 95 | 82 | 72 | 97 | 85 | 75.8 |
| Dec. 9 Quiet.... | 93 | 114 | 112 | 117 | ..... | 91 | 123 | 124 | ..... | 108 | 86 | 127 | 109 | 100 |
| Active... | 68 | 63 | 71 | 72 | ..... | 68 | 76 | 85 | ..... | 70 | 64 | 96 | 74 | 67.9 |
| Rest..... | 67 | 91 | 73 | 84 | ..... | 80 | 92 | 101 | ..... | 71 | 64 | 98 | 85 | 78.0 |
| Jan. 13 Quiet.... | 92 | 90 | 101 | 95 | 100 | 90 | 109 | 108 | 105 | ..... | (1) | 127 | 102 | 100 |
| Active... | 73 | 66 | 67 | 67 | 73 | 71 | 79 | 77 | 84 | ..... | ..... | 93 | 76 | 74.5 |
| Rest..... | 77 | 80 | 70 | 68 | 86 | 84 | 84 | 89 | 84 | ..... | ..... | 95 | 83 | 81.4 |
| Jan. 27 Quiet.... | 112 | 111 | 126 | 147 | 112 | 107 | 125 | 120 | 141 | ..... | 88 | 138 | 120 | 100 |
| Active... | 84 | 74 | 79 | 87 | 71 | 73 | 88 | 91 | 97 | ..... | 65 | 103 | 83 | 69.2 |
| Rest..... | 84 | 82 | 84 | 92 | 89 | 105 | 100 | 101 | 105 | ..... | 64 | 108 | 93 | 77.5 |
| Low-diet average: | | | | | | | | | | | | | | |
| Quiet........ | 97 | 106 | 115 | 119 | 91 | 97 | 119 | 125 | 124 | 104 | 87 | 124 | 109 | 100 |
| Active....... | 72 | 73 | 77 | 73 | 68 | 68 | 82 | 88 | 87 | 69 | 65 | 95 | 77 | 70.6 |
| Rest......... | 73 | 82 | 79 | 78 | 79 | 87 | 91 | 99 | 93 | 73 | 67 | 96 | 85 | 78.0 |
| P. ct. change: | | | | | | | | | | | | | | |
| Active....... | 74.2 | 68.9 | 67.0 | 61.4 | 74.7 | 70.1 | 68.9 | 70.4 | 70.2 | 66.3 | 74.7 | 76.6 | 70.6 | ..... |
| Rest......... | 75.3 | 77.4 | 68.7 | 65.6 | 86.8 | 89.6 | 76.4 | 79.2 | 75.0 | 70.2 | 77.0 | 77.4 | 78.0 | ..... |

[1] On account of the operation which *Tom* had in early January he was not asked to do the chinning on this date.

each have 124 for pulse-cycle length corresponding with a rate per minute of 48 beats. The pulse-cycle length during activity shows a range from 65 to 95 for *Tom* and *Vea*, respectively. It is worthy of note that *Vea*, whose pulse has been spoken of in other connections (see p. 387) as so remarkably low, showed a cycle-length during activity considerably longer than that of *Pec* and *Pea*, whose quiet pulse length was at the same level with *Vea*. On the other hand, *Pea* and *Pec* show greater changes between activity and the subsequent rest than does *Vea*. The resting level ranges from 67 to 99 for *Tom* and *Pea*, respectively. In terms of per cent the activity is from 61.4 to 76.6 (*Gar* and *Vea*) of the quiet pulse-cycle length and the resting percentage is from 65.6 to 89.6 with *Gar* and *Mon*, the latter demonstrating unusually quick recovery in pulse-cycle length following the activity.

For Squad B records were taken on two normal dates, November 18 and December 16, and on two of the low-diet dates, January 14 and January 20. (See table 95.) The averages at the right-hand of the table do not include the values for *McM*, *Kim*, and *Sch*. The other 10 men show averages for November 18 of 94, 67, and 70, for conditions of quiet, activity, and rest, respectively. In per cent of the pulse-cycle length during quiet, the activity and rest are 71.3 and 74.2, respectively. The average pulse-cycle length for the two nor-

TABLE 95.—*Different levels of pulse-cycle length with conditions of quiet, activity, and rest for men of Squad B.*

[Values in 0.01 second for pulse-cycle length.]

| Experiment and condition. | Fis. | Har. | How. | Ham. | McM. | Kim. | Lon. | Sch. | Liv. | Sne. | Tho. | Van. | Wil. | Av. | P. ct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Normal:* | | | | | | | | | | | | | | | |
| Nov. 18 Quiet | 101 | 93 | 68 | 82 | 82 | ..... | 108 | ..... | 99 | 84 | 112 | 98 | 96* | 94 | 100 |
| Active | 74 | 68 | 58 | 61 | 67 | ..... | 81 | ..... | 73 | 58 | 69 | 61 | 71 | 67 | 71.3 |
| Rest | 73 | 68 | 59 | 69 | 63 | ..... | 75 | ..... | 69 | 70 | 76 | 74 | 64 | 70 | 74.5 |
| Dec. 16 Quiet | ..... | 91 | 67 | ..... | 88 | ..... | 108 | 60 | 101 | 83 | ..... | 93 | 90 | 90 | 100 |
| Active | ..... | 70 | 57 | ..... | 67 | ..... | 79 | 51 | 72 | 58 | ..... | 63 | 71 | 67 | 74.4 |
| Rest | ..... | 72 | 56 | ..... | 76 | ..... | 81 | 54 | 68 | 66 | ..... | 76 | 69 | 70 | 77.8 |
| Normal average: | | | | | | | | | | | | | | | |
| Quiet | 101 | 92 | 68 | 82 | ..... | ..... | 108 | ..... | 100 | 84 | 112 | 96 | 93 | 92 | 100 |
| Active | 74 | 69 | 58 | 61 | ..... | ..... | 80 | ..... | 73 | 58 | 69 | 62 | 71 | 67 | 72.8 |
| Rest | 73 | 70 | 58 | 69 | ..... | ..... | 78 | ..... | 69 | 68 | 76 | 75 | 67 | 70 | 76.1 |
| Per cent change: | | | | | | | | | | | | | | | |
| Active | 73.3 | 75.0 | 85.3 | 74.4 | ..... | ..... | 84.0 | ..... | 73.0 | 69.0 | 61.6 | 64.6 | 76.3 | 72.8 | ..... |
| Rest | 72.3 | 76.0 | 85.3 | 84.2 | ..... | ..... | 72.1 | ..... | 69.0 | 81.0 | 67.8 | 78.1 | 72.0 | 76.1 | ..... |
| *Low-diet:* | | | | | | | | | | | | | | | |
| Jan. 14 Quiet | 104 | 98 | 81 | 91 | ..... | 97 | 109 | 105 | 118 | 80 | 130 | 122 | 103 | 104 | 100 |
| Active | 75 | 78 | 59 | 65 | ..... | 71 | 85 | 68 | 79 | 59 | 98 | 72 | 78 | 75 | 72.1 |
| Rest | 76 | 67 | 55 | 62 | ..... | 80 | 72 | 72 | 89 | 57 | 95 | 85 | 72 | 73 | 70.2 |
| Jan. 20 Quiet | 105 | 115 | 87 | 89 | ..... | 93 | 103 | 136 | 115 | 100 | 115 | 113 | 101 | 104 | 100 |
| Active | 75 | 77 | 78 | 73 | ..... | 73 | 86 | 83 | 74 | 67 | 80 | 67 | 78 | 76 | 73.1 |
| Rest | 79 | 83 | 72 | 76 | ..... | 76 | 82 | 90 | 79 | 66 | 95 | 89 | 81 | 80 | 76.9 |
| Low-diet av'g: | | | | | | | | | | | | | | | |
| Quiet | 105 | 107 | 84 | 90 | ..... | 95 | 106 | 121 | 117 | 90 | 123 | 118 | 102 | 104 | 100 |
| Active | 75 | 78 | 69 | 69 | ..... | 72 | 86 | 76 | 77 | 62 | 89 | 70 | 78 | 76 | 73.1 |
| Rest | 78 | 75 | 64 | 69 | ..... | 78 | 77 | 81 | 84 | 62 | 95 | 87 | 77 | 77 | 74.0 |
| Per cent change: | | | | | | | | | | | | | | | |
| Active | 71.4 | 72.9 | 82.2 | 76.6 | ..... | 75.8 | 81.2 | 62.9 | 65.8 | 70.0 | 69.5 | 59.3 | 76.4 | 73.0 | ..... |
| Rest | 74.3 | 70.1 | 76.2 | 76.6 | ..... | 82.1 | 72.6 | 67.0 | 71.8 | 68.9 | 74.2 | 73.7 | 75.4 | 74.0 | ..... |

mal dates and for the three conditions in the records, as shown in the right-hand column of table 95, are 92, 67 and 70, the latter two values being 72.8 and 76.1 per cent, respectively, of the pulse-cycle length during quiet. The individual subjects show no marked peculiarity, except in the comparison of the pulse-cycle lengths for activity and rest. During the 20 beats in the rest following the activity five of the subjects, *Fis*, *How*, *Lon*, *Liv*, and *Wil*, have pulse-cycles as short as or shorter than during the activity. In other words, after the activity the pulse tended to remain high for a period. Thus we have a difference between the conditions of activity and rest (72.8 and 76.1) of only 3.3 per cent in the case of Squad B, while with Squad A the resting pulse-cycle length was 7.4 per cent longer than the cycle length during activity. In the average for the two low-diet experiments, several Squad B men show the same condition, that is, a faster pulse following the activity. Hence it can not be assumed that the contrast between the normal of Squad B and the records of Squad A is due to the reduced diet.

The average quiet, activity, and rest values with the percentage of change from the quiet as shown by activity and rest are, for com-

parison, summarized in table 96. In this are embodied, also, the results of normal series of 1917. Records, usually two for each man, obtained with 63 normal aviation candidates enter into this 1917 series. The technique employed with these men was identical with that used in this investigation and described on page 151, except that the first trial was not a practice trial without a record, as in the low-diet investigation, but with the aviators a record was taken. Thus the pulse-rate in the first record for the aviators was affected somewhat by the factor of excitation and novelty. It is possible that this in large part accounts for the difference between their average of 83 for the quiet pulse-cycle length and 92 for the normal average of the same measurement with Squad B, and likewise for the fact that the activity and rest values, 60 and 65, are shorter than the normal values of Squad B, *i. e.*, 67 and 70. However, both the normal values for Squad B and

TABLE 96.—*Summary for pulse changes occasioned by short periods of exertion.*

[Values in 0.01 second for pulse-cycle length.]

| Groups of subjects and conditions compared. | Quiet. | Activity. | Rest. | Activity, p. ct. of change. | Rest, p. ct. of change. |
|---|---|---|---|---|---|
| Squad A, low-diet........ | 109 | 77 | 85 | 29 | 22 |
| Squad B, normal......... | 92 | 67 | 70 | 27 | 25 |
| Squad B, low-diet........ | 104 | 76 | 77 | 27 | 26 |
| Normal series of 1917..... | 83 | 60 | 65 | 27 | 21 |

those in the series of 1917 definitely show shorter pulse-cycle lengths than the values for the low-diet period of Squad B and those of Squad A. Compared on the basis of percentage of change of the activity over the pulse-cycle length during quiet, we have for Squad A 29 per cent and for all the others 27 per cent—surely a remarkably close correspondence. The percentage of change in the 20 pulse-cycles following activity, as compared to the quiet pulse-cycle length, is for Squad A 22 per cent, while that for the normal series of 1917 is 21 per cent. With Squad B, also, the low-diet value is 1 per cent larger than the normal, being 26 per cent as compared with 25 per cent. As was mentioned earlier, certain of the members of Squad B demonstrated individual peculiarities, having a faster pulse than would normally be expected after activity.

Finally, we may compare the composite curves, which show not simply the levels in the three different conditions, quiet, activity, and rest, as presented and discussed in tables 94, 95, and 96, but also demonstrate the transitions and the progressive changes between these. An average was made for the comparable pulse-cycles of the 10 subjects of Squad A for three of the dates on which such tracings were taken for these men.[1] The average values obtained for these dates, to-

[1] We have omitted from the average the records of *Kon* and *Sps*.

gether with a similar average obtained for all of the records of the 63 men of the series of 1917, are plotted in curves and embodied in figure 93. A similar series of curves for Squad B, together with the average for the series of 1917, are presented in figure 94. As explained on page 416, two records, such as are illustrated in figure 24, were taken for each subject and date; therefore, as 10 subjects are averaged, each plotting-point is usually the average length of 20 pulse-cycles. The 6 pulse-cycles immediately preceding the beginning of activity were used

FIG. 93.—Composite curves for changes in pulse-cycle duration with exertion, Squad A—Records for 3 days with Squad A compared with the results for normal series of 1917.

to indicate the level of the quiet pulse. The first 20 cycles following the end of activity were taken as indicative of the changes in the period of rest after exertion. Since in our procedure the duration of activity was made as constant as practicable, the *number* of pulse-cycles which came within this limit was naturally a function of the pulse-rate and varied with different subjects. This, unfortunately, when one averages the records, causes an irregularity at the point of transition from activity to rest. In figure 93 the curves for Squad A show an irregular rise at this point due to the predominating influence of these faster pulse-rates. (See *Gul* and *Tom*, table 94.)

In all of the curves for Squads A and B, the major portion of the period of activity and also of the period of subsequent rest have a very

great uniformity, that is, the averages make very smooth curves. There is apparently no significant difference with Squads A, B, and the normal series of 1917 in the sharpness of the rise with beginning activity. The absolute change in hundredths of a second between the level for quiet and the level for activity is of course greater in those cases in which the level for quiet is low, as for example, on January 27 with Squad A (fig. 93), but, as we have seen previously, the percentage of change is about the same in each case. The irregularity at the beginning during the period of quiet is somewhat larger than would be expected, judging from the curve for the series of 1917. These irregularities, considered on the percentage basis, would not be as relatively

FIG. 94.—Composite curves for changes in pulse-cycle duration with exertion, Squad B—Records for 4 days with Squad B compared with the results for normal series of 1917.

large as they appear in the figure. It seems probable that at the lower pulse-rate the natural arrhythmia is accentuated. The descending portion of the curves is usually consistent in its uniformity until it reaches approximately the sixteenth pulse-cycle. Subsequently there is considerable fluctuation. From figure 93 it would appear that the return in the direction of the basal level for quiet is more prompt for Squad A than in the case of the normal series for 1917. If one had only these data it might be taken as an indication of a different condition due to the lower pulse-rate during the reduced diet. When we compare the curves for Squad B, however (see fig. 94), we find no sensible difference in their slope as compared with the normal series of 1917, and the normal curves of Squad B compare very favorably with those taken during the period of reduced diet.

The electrocardiograms taken to show the changes in heart rate due to short periods of general muscular exertion fail to demonstrate any pathological conditions, judged in the light of the available standards with which we may compare such records. No subject ever complained in connection with the test or asked to be excused or indicated any fatigue following the exercise. The only consistent difference exhibited between the men on reduced diet and those with uncontrolled diet is in the pulse-rate level, irrespective of whether we compare periods of quiet when the subject is relaxed, periods of exertion when the larger part of the voluntary musculature is under tension, or periods of rest following such activity. The percentage of rise in the pulse-rate occasioned by such activity, which is found on the average in the 20 pulse-cycles immediately following the activity, shows no significant change with reduced diet. It therefore appears certain that the lower nutritional level produced by continued low diet did not interfere with the ability for adaptive increase in heart rate under conditions of muscular exertion, when the needs of the organism naturally required an increase in the circulation. Furthermore, it may be stated that no annoying cardiac or respiratory symptoms, other than the described normal changes, followed these periods of exertion. In all the records there were no cases of extra systoles or skipped beats.

## TRANSITION PULSE.

At the time of the treadmill experiments of January 28 and February 3, described on page 440, continuous electrocardiograms were taken on each subject during 15 seconds of standing and the immediately succeeding 60 seconds at the beginning of walking, and then again during the last 15 seconds of walking and the following 30 seconds of standing. The data thus obtained show the changes in duration of the pulse cycles as the pulse-rate alters during the successive seconds of walking or of standing. They also show how quickly the heart reacts to the stimulus and at which cycle the pulse has reached its maximum rate. We have termed these measurements the *transition pulse* as they were taken during the time that the heart was adjusting itself to the altered demands made upon it by the changed conditions of either walking or standing.

These measurements can best be presented graphically. Figures 95, 96, and 97 give the curves representing the transition pulse of the individual members of Squad B on January 28, 1918, and figures 98, 99, and 100 show those for Squad A on February 3, 1918. Since the measurements of the transition pulse were first made on January 28, there are no basal data for any of these subjects, *i.e.*, no data taken when the men were living on a normal diet. To supply this lack of basal material, five members of the Laboratory staff went through the walking routine in the post-absorptive condition during the week of

February 14 to 19, 1918, records being made of their transition pulse. The curves for these normal subjects appear in figure 101. In these figures the durations of the pulse cycles, calculated in 0.01 seconds, appear as ordinates. The abscissæ show the number of pulse cycles. The curves have been drawn so that each plotted point represents the average of two cycles, thus diminishing the small variations present in the normal heart action and producing a smoother curve. The heavy lines $X$ and $Y$ indicate the moment of transition from standing to walking and the reverse. The pulse cycles to the left of $X$ represent the preliminary standing period. Those to the right of $X$ represent the initial walking period. Similarly, the cycles to the left of $Y$ are for walking and those to the right of $Y$ are for standing. Between these two transition curves, there has also been inserted a short curve representing the pulse-rate at the sixth, twelfth, and twenty-fourth minutes of walking. Thus there are shown for each subject (1) the curve for the walking transition following standing; (2) the curve for the standing transition following walking; and (3) a curve for the pulse-rate at three points, usually after 6, 12, and 24 minutes of walking. The approximate pulse-rate corresponding to the length of pulse cycle is given on the right of the figure. Intervals of approximately 15 seconds are shown by the smaller figures at the bottom of each transition curve. The sixth, twelfth, and twenty-fourth minutes are also indicated on this line for the intervening walking curve, but it should be clearly understood that the times between these points, as represented by the abscissæ, are not uniform. For instance, with *Fis*, the time covered by the preliminary standing pulse record was 14.3 seconds. The first twenty cycles of walking lasted 15.4 seconds, while the entire walking portion of this transition record was 59.7 seconds. There is then an interval of slightly over 5 minutes before the pulse-rate for the sixth minute, and intervals of 6 and 12 minutes between the next two points. After the twenty-fourth minute, there is an elapsed period of approximately 2 minutes before standing began at $Y$. The ten pulse cycles of walking preceding the standing lasted 9.2 seconds, while the standing record was 28.6 seconds.

### TRANSITION PULSE, SQUAD B.

It is hardly necessary to analyze each individual curve shown in the succeeding figures. The chief points of resemblance and difference can be brought out by considering a few curves from each group. In the pulse of *Fis* shown in figure 95, the average length of the first two pulse cycles noted was 1.16 seconds. The average of the next two pulse cycles was 1.10 seconds, after which the duration changed to 1.22 seconds for the average of the fifth and sixth cycles. From this point the duration of the pulse cycles shortened, and at the transition, $X$, the length was 0.99 second. The shortening of the duration of the

FIG. 95.—Transition pulse curves for Fisher, Hammond, Hartshorn, and Howland, Squad B, January 28, 1918.

The curves show the changes in the duration of the pulse cycles at the transition from standing to walking and also from walking to standing. X, transition point, standing-walking; Y, transition point, walking-standing. Duration of pulse cycle is given in 0.01″. Each plotted point is the average of two cycles. The equivalent pulse-rate per minute is shown at the right. The elapsed time is given in seconds in smaller type at the bottom. The pulse-rates at the sixth, twelfth, and twenty-fourth minutes of walking are inserted between the two transition curves and indicate the pulse-rates as the walking progressed.

cycle continued until the tenth cycle after walking started, which was 0.80 second; it then remained practically constant through the sixteenth beat, after which the duration began to lengthen again and continued lengthening until the twenty-second cycle. There followed, then, a period of some slight variations up to the thirtieth beat, after which a second period of quickened pulse—*i. e.*, shorter duration of pulse cycle—set in and by the time of the thirty-fourth cycle it had returned to the value observed at the tenth cycle. This corresponds approximately to 29 seconds after the walking started. From this point there was a gradual lengthening of the pulse cycle to the close of the record. The last cycle of the transition period corresponds to a duration of 0.83 second, which was after 59.7 seconds of walking. The pulse-rates taken for the sixth, twelfth, and twenty-fourth minutes of the succeeding interval of walking appear here as a short curve and show, in a general way, the relation of the pulse to the transitional rate as the period progressed. It is seen in the final portion of the figure that the duration of the pulse cycle was nearly uniform for the 10 cycles preceding the close of walking, and was 0.77 second at the moment of transition. The average of the first two pulse cycles of the standing period shows an immediate lengthening to 0.82 second, when again a period of shortening rate followed, which was maintained, more or less irregularly, for 34 beats during the next 27 seconds.

The curve for *Har* (figure 95) is fragmentary, as certain portions of the time record of the photographic film were illegible and the first direct reading of the walking pulse comes approximately 4.5 seconds after the transition. This shows a change in the duration of the pulse cycle from 1.24 second at *X* to 0.84 second as the average of the fifth and sixth cycles. Between the tenth and twentieth cycles the records are missing, but the twentieth shows a slight lengthening, after which a shortening of the pulse cycle took place which reached its maximum at the forty-fourth cycle and was maintained with slight variations to the close of this part of the record. During the rest of the walking period, the pulse cycle lengthened somewhat, and by the time of the final transition was 0.84 second. When the subject stopped walking the cycles immediately began to lengthen and were 0.99 second at the end of the record.

Other members of the squad present similar pictures in the curves given in figures 96 and 97. In the case of *Kim* (figure 96) the duration was 0.79 second with the third and fourth cycles after walking began; a marked lengthening to 0.93 second appeared in the average of the fifth and sixth cycles. This was followed by a series of periods of changing length of the pulse cycles which appear to indicate a rhythm in the pulse. In the transition from walking to standing the first immediate lengthening was followed by a shortening of the cycles, so that the cycle is shorter from the tenth to the fourteenth cycles after walking ceased than during the walking period.

FIG. 96.—Transition pulse curves for Kimball, Livingstone, Schrack, and Snell, Squad B, January 28, 1918.

For detailed explanation, see figure 95.

*Liv* (figure 96) is the only subject whose pulse cycles do not show a marked lengthening in the duration following the first stimulus of walking. The sixth cycle lengthened slightly to 1.10 seconds, but the curve is in marked contrast to the others and with minor variations is that of a constantly shortening pulse cycle. The immediate lengthening of the cycle at the end of walking continued only through the eighth beat, when it was again followed by a marked shortening period for 6 cycles, after which it continued with an irregularly lengthening interval.

The curve for *Tho* (figure 97) is in the main like the others, but as only 29.7 seconds of the walking transition was secured, it is incomplete. An incipient lengthening of the cycle took place at the sixth beat, but the marked change did not occur until the fourteenth beat, when the duration changed from 0.96 to 1.13 seconds by the twenty-fourth cycle. At that point the quickening of the pulse apparently began, but the record here is incomplete. The pulse cycle was fairly uniform for the 9 cycles at the end of walking, with a duration of 1.18 seconds. This is approximately the duration of the original standing cycle. The cycle reached its maximum length of 1.39 seconds at the tenth beat, after which it shortened to 1.23 seconds at the twentieth beat.

The general picture which these figures for Squad B present is that of a rising curve—*i. e.*, a shortening pulse cycle—beginning from 4 to 8 cycles before the transition to walking and continuing through the transition for a period rarely exceeding 12 cycles, and often not over 4 cycles. The curve then descends, reaching its maximum depression at or near the twentieth cycle, from which a second ascending curve begins.

At the final transition to standing less regularity is seen, but in general it may be said that the response by the heart is prompt, and the curve descends to a minimum at about the tenth cycle, after which there is a more or less pronounced rise, persisting for a few cycles, and then a tendency to fall slightly.

The initial rise while the subject was still standing before walking is accounted for from the routine of the experiment. Previous to the taking of the photographic record the subject had been standing quietly on the treadmill for some time. At a certain moment the assistant gave audible warning to the other assistants that he would start the mill in 15 seconds. This warning could be heard by the subject in the chamber, and a psychically stimulated pulse-rate followed in anticipation of the beginning of walking. The acceleration due to the anticipation of the starting of the treadmill makes it difficult to compare the pulse-cycle durations of the period of standing preliminary to walking with the pulse-cycle durations during walking. Some of the curves indicate that this psychological disturbance is

partially or wholly overcome by the time the walking began, but the majority show that it extended into the walking period. To have given the subject no warning at all would have been equally disturbing for the surprise of the sudden starting of the treadmill would have given the pulse an undue stimulus which would not have been a part of the effort of walking.

FIG. 97.—Transition pulse curves for Thompson, Van Wagner, and Williams, Squad B, January 28, 1918.

For detailed explanation, see figure 95.

While recognizing the difficulty of selecting a value that would represent the normal pulse-cycle duration for the period of standing preceding walking, due to the psychical disturbance and the shortness of the preliminary standing record, we have nevertheless attempted to make such a selection and find that the pulse-cycle durations while standing were approximately as follows: *Fis*, 1.13; *Ham*, 1.08; *Har*, 1.19; *How*, 0.95; *Kim*, 0.95; *Liv*, 1.36; *Sch*, 1.47; *Sne*, 1.00; *Tho*, 1.15; *Van*, 1.48; and *Wil*, 1.26. Using these figures as a base line, we find that the change to the first peak of the shortened cycles during walking ranged from 0.05 second for *How* to 0.53 second for *Sch*, the average change for the squad being 0.29 second. If these standing pulse cycles are compared with those obtained from the pulse-rates plotted for the sixth and twenty-fourth minutes of walking, it is found that after 6 minutes of walking there has been a change which on an average for the squad would correspond to a shortening in the duration of the pulse cycle equivalent to 0.25 second, while for 24 minutes the change would correspond to 0.30 second.

The average durations of the pulse cycles during the few seconds of walking preceding standing as shown by the curves are as follows: *Fis*, 0.76; *Ham*, 0.84; *Har*, 0.85; *How*, 0.83; *Kim*, 0.78; *Liv*, 1.02; *Sne*, 0.80; *Tho*, 1.18; *Van*, 0.94. At the tenth, twentieth, and thirtieth cycles for standing after walking, the durations of the pulse cycles have lengthened from these figures, on an average for the squad, 0.06, 0.07, and 0.02 second, respectively. When the durations at the same three points are compared with the average standing duration preliminary to walking, we find a shorter duration in the post-walking period, the differences being 0.19, 0.18, and 0.19 second, respectively.

## TRANSITION PULSE, SQUAD A.

Figures 98 to 100 give the series obtained with Squad A on February 3, 1918, after a long-continued period of restricted diet. The first curve, that of *Bro* (figure 98), shows the usual change in length of the pulse cycle on the first intimation that the treadmill was to start, which persisted for 8 beats and then gradually lengthened so that at the transition point the pulse cycle was again at its normal length of 0.88 second. As soon as the walking began the duration of the cycle change , and at the fourth beat had shortened to 0.75 second. A slight lengthening followed, so that the duration of the tenth cycle was 0.79 second. The main lengthening, however, took place between the eighteenth an twenty-sixth cycles, when the duration of the pulse cycle changed from 0.74 to 0.88 second. The length of the cycle gradually grew less from this point until the end of this part of the record, but at no time did it become as short as at the first stimulus of walking. In passing from walking to standing, no marked tendency is indicated for a lengthening of the pulse cycle, until after the twentieth cycle,

when the duration changed from 0.79 to 0.86 second at the twenty-sixth beat. After shortening again to 0.81 second at the thirtieth cycle, the duration changed to 0.90 second at the end of the record. The character appears, then, to be the same as in the curves discussed, but with the changes in the cycle lengths slightly delayed. The curve on the whole is more uniform than the others in the group which follow it.

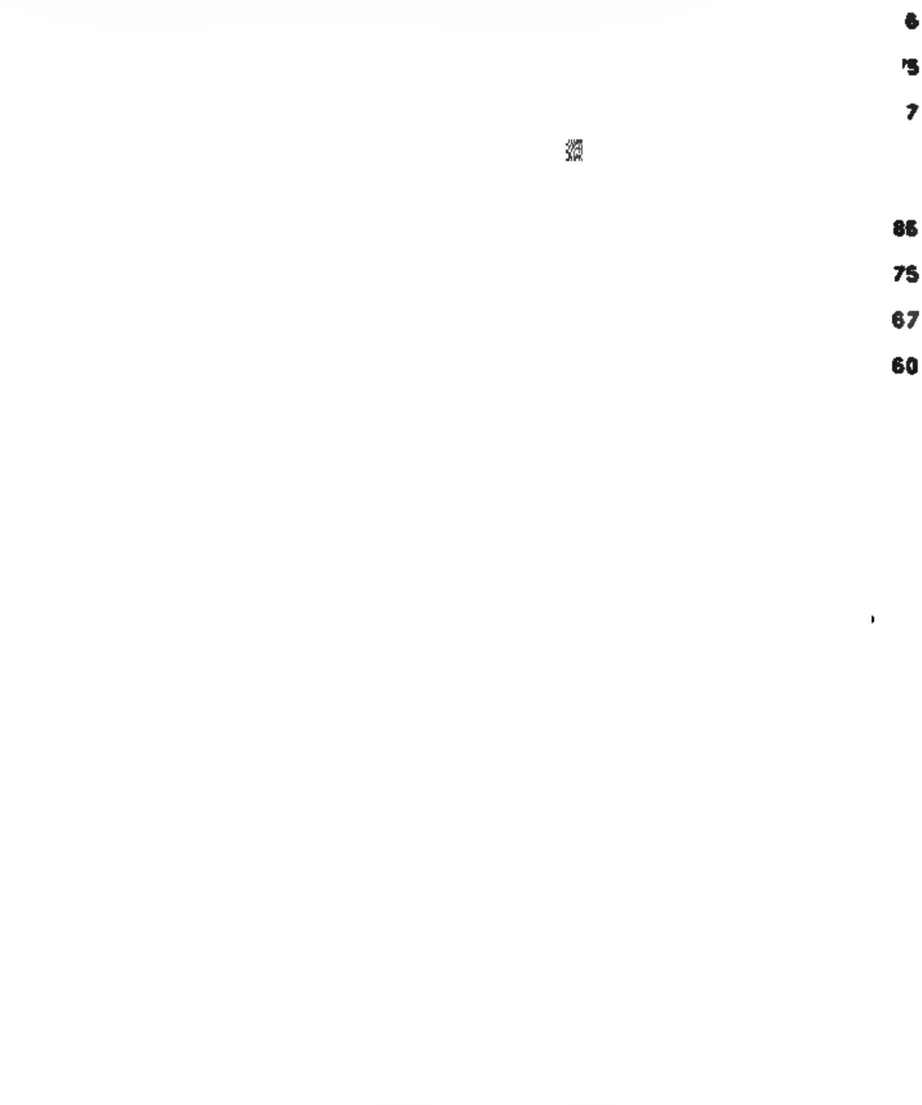


FIG. 98.—Transition pulse curves for Brown, Canfield, Kontner, and Gardner, Squad A, February 3, 1918.

For detailed explanation, see figure 95.


FIG. 99.—Transition pulse curves for Gullickson, Montague, and Moyer, Squad A, February 3, 1918.

For detailed explanation, see figure 95.

next 8 beats, when a fairly uniform shortening occurred. The curve for the standing transition is, in general, not unlike that shown for the majority of the other subjects. The final cycle measured has a duration of 1.19 seconds, which is slightly longer than the standing cycles preliminary to walking.

In the walking transition curve for *Vea* (figure 100), the maximum shortening of the pulse cycle appears to have been reached at the eighth beat, with a duration of 1.00 second, which is maintained through the twelfth cycle. At the thirteenth cycle the photographic tracing shows that *Vea's* heart skipped a beat and in measuring the duration of the double cycle in which the missing thirteenth beat occurred, the average for two beats has been taken although only one beat (the fourteenth) showed on the record. This pulse cycle is marked by an asterisk (*) in the curve. It is seen that the heart tried to make up for this skip by a quickening of the rate in the succeeding two cycles, the duration showing a change from 1.02 to 0.96 second. This is the only instance of a skipped beat noted in all the records. With this exception, the curve of *Vea* is not unlike that of the others in this group.

The average durations of the pulse cycles for standing preliminary to the walking transition, estimated as for Squad B, page 431, are as follows: *Bro*, 0.86; *Can*, 0.82; *Kon*, 1.19; *Gar*, 1.38; *Gul*, 0.96; *Mon*, 1.02; *Moy*, 1.16; *Pea*, 1.05; *Tom*, 0.76; *Vea*, 1.16. The differences between these standing pulse-cycle durations and those for the minimum duration, which immediately follows the change to walking, range from 0.11 second for *Bro* to 0.55 second for *Gar*, with an average change for the squad of 0.24 second. Comparing these standing pulse-cycle durations with the durations which would correspond to the pulse-rates after the sixth and twenty-fourth minutes of walking, we find that the average change has been to shorten the duration 0.15 second for 6 minutes of walking and 0.20 second for 24 minutes of walking.

The average durations of the pulse cycles for Squad A just before walking ceased are found from the curves to be as follows: *Bro*, 0.81; *Can*, 0.81; *Kon*, 0.88; *Gar*, 0.96; *Gul*, 0.77; *Mon*, 0.81; *Moy*, 0.94; *Pea*, 0.92; *Tom*, 0.65; *Vea*, 0.94. Comparing these figures with the durations at the tenth, twentieth, and thirtieth cycles after walking ceased, as was done with Squad B, we find that the average pulse cycle for

FIG. 100.—Transition pulse curves for Peabody, Tompkins, and Veal, Squad A, February 3, 1918.

For detailed explanation, see figure 95.

the squad has lengthened in its duration over that of walking 0.15, 0.10, and 0.09 second, respectively, while at these same points the pulse cycle is shorter than the average duration for the preliminary standing period by 0.05, 0.08, and 0.08 second, respectively.

### TRANSITION PULSE OF A GROUP OF NORMAL MEN.

As was stated at the beginning of this discussion, no transition pulse records were taken while the subjects were living on a normal diet, so that to secure data for purposes of comparison, 5 members of the staff of the Laboratory volunteered to go through the same walking routine in the post-absorptive condition, although no blood-pressure measurements were made at the end of walking. The transition pulse cycles of these men are given in figure 101.

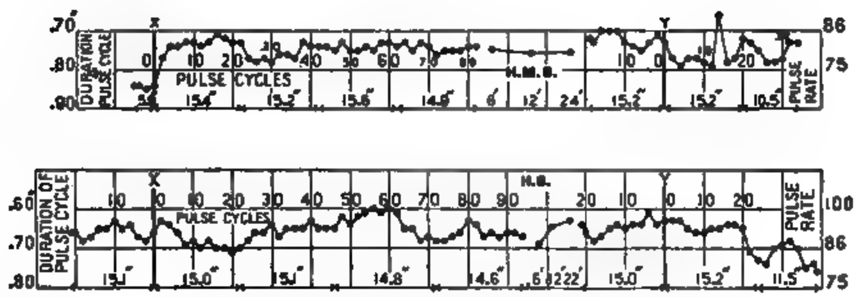


FIG. 101.—Transition pulse curves for a group of five normal men.
For detailed explanation, see figure 95.

TABLE 98.—*Pulse-rate preceding, during, and following walking in the treadmill chamber and percentage change from the standing rate—Squad B, normal, January 6, 1918.*

| Subject. | Rate per minute. | | Rate at minutes after walking began. | | | | Sitting outside chamber. Rate at minutes after walking ceased. | |
|---|---|---|---|---|---|---|---|---|
| | Sitting outside chamber. | Standing outside chamber. | 1′ | 6′ | 12′ | 24′ | 2′ | 7′ |
| *Fis:* | | | | | | | | |
| Rate........ | 73 | 82 | 81 | 78 | 79 | 86 | 62 | 68 |
| P. ct. change. | ........ | ........ | − 1 | − 5 | − 4 | − 5 | ........ | ........ |
| *Har:* | | | | | | | | |
| Rate........ | 68 | 79 | 96 | 88 | 88 | 92 | 62 | 64 |
| P. ct. change. | ........ | ........ | 22 | 11 | 11 | 16 | ........ | ........ |
| *How:* | | | | | | | | |
| Rate........ | ........ | 77 | 96 | 91 | 96 | 101 | 84 | 82 |
| P. ct. change. | ........ | ........ | 25 | 18 | 25 | 31 | ........ | ........ |
| *Ham:* | | | | | | | | |
| Rate........ | 82 | 95 | 94 | 95 | 99 | 104 | 72 | 76 |
| P. ct. change. | ........ | ........ | − 1 | 0 | 4 | 9 | ........ | ........ |
| *Kim:* | | | | | | | | |
| Rate........ | 70 | 80 | 86 | 87 | 83 | 90 | 72 | 74 |
| P. ct. change. | ........ | ........ | 8 | 9 | 4 | 13 | ........ | ........ |
| *McM:* | | | | | | | | |
| Rate........ | 76 | 84 | 100 | 100 | 89 | 90 | 72 | 76 |
| P. ct. change. | ........ | ........ | 19 | 19 | 6 | 7 | ........ | ........ |
| *Sch:* | | | | | | | | |
| Rate........ | 92 | 68 | 83 | 80 | 85 | 78 | 60 | 54 |
| P. ct. change. | ........ | ........ | 22 | 18 | 25 | 15 | ........ | ........ |
| *Liv:* | | | | | | | | |
| Rate........ | 69 | 71 | 70 | 73 | 79 | 76 | 62 | 60 |
| P. ct. change. | ........ | ........ | − 1 | 3 | 11 | 7 | ........ | ........ |
| *Sne:* | | | | | | | | |
| Rate........ | 97 | 69 | 90 | 88 | 86 | 91 | 70 | 76 |
| P. ct. change. | ........ | ........ | 30 | 28 | 25 | 32 | ........ | ........ |
| *Tho:* | | | | | | | | |
| Rate........ | 56 | 77 | 77 | 75 | 78 | 82 | 52 | 56 |
| P. ct. change. | ........ | ........ | 0 | − 3 | 1 | 6 | ........ | ........ |
| *Van:* | | | | | | | | |
| Rate........ | ........ | ........ | 83 | 80 | 81 | 84 | 54 | 56 |
| P. ct. change. | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| *Wil:* | | | | | | | | |
| Rate........ | 78 | 83 | 96 | 88 | 83 | 93 | 64 | 62 |
| P. ct. change. | ........ | ........ | 16 | 6 | 0 | 12 | ........ | ........ |
| Average..... | [1]72 | 79 | 88 | 85 | 85 | 89 | 66 | 67 |
| P. ct. change. | ........ | ........ | 11 | 8 | 8 | 13 | ........ | ........ |

[1]Omitting *Sch* and *Sne*.

pulse. At the twelfth minute the average pulse-rate was like that of the sixth minute and by the end of 24 minutes it was but 1 beat per minute higher than at the end of the first minute of walking.

The sitting pulse following walking, which was taken at the wrist, had an average of 66 beats by the second minute; this was below the sitting pulse taken photographically before walking. It was still below the initial pulse after 7 minutes of sitting, although there was a slight rise to 67 beats. If these pulse-rates were plotted with the rate as ordinates and the time as abscissæ, the resultant curves would show a fall between the end of the first and of the sixth minutes, followed by

TABLE 99.—*Pulse-rate per minute preceding, during, and following walking in the treadmill chamber with percentage change from rate standing in chamber before walking—Squad B, January 25, 1915.*

[1]Rate at 7 minutes. [2]Based on rate standing outside chamber. [3]Rate at 10 minutes. [4]Rate at 8 minutes.

TABLE 100.—*Pulse-rate per minute preceding, during, and following walking in the treadmill chamber with percentage change from rate standing in chamber before walking—Squad A, February 3, 1918.*

| Subject. | Rate per minute. | | | Rate at minutes after walking began. | | | | | | | | | | | | | | | | | | | | | | Standing in chamber, cover open; rate at seconds after walking ceased. | | | | Sitting outside chamber, rate after walking ceased. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sitting outside chamber. | Standing outside chamber. | Standing in chamber, cover open. | 1′ | 2′ | 3′ | 4′ | 5′ | 6′ | 7′ | 8′ | 9′ | 10′ | 11′ | 12′ | 14′ | 15′ | 16′ | 17′ | 18′ | 19′ | 20′ | 22′ | 23′ | 24′ | 30″ | 60″ | 90″ | 120″ | 4′ | 8′ | 9′ |
| *Bro:* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rate | 60 | 64 | 68 | 76 | 74 | 73 | 74 | 75 | 73 | ... | 79 | 78 | 76 | ... | 75 | 74 | ... | 77 | ... | 78 | ... | 73 | 74 | 74 | 75 | 70 | 70 | 69 | 70 | 55 | ... | 57 |
| P. ct. change | ... | ... | ... | 12 | 9 | 7 | 9 | 10 | 7 | ... | 16 | 15 | 12 | ... | 10 | 9 | ... | 13 | ... | 7 | ... | 7 | 9 | 9 | 10 | 3 | 3 | 1 | 3 | ... | ... | ... |
| *Can:* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rate | 62 | 81 | 67 | 74 | 67 | 65 | 69 | 69 | 66 | 69 | 68 | ... | 72 | ... | 71 | 69 | ... | 68 | ... | 70 | ... | 75 | ... | ... | 73 | 75 | 70 | 78 | 82 | 48 | ... | 63 |
| P. ct. change | ... | ... | ... | 10 | 0 | −3 | 3 | 3 | −1 | 3 | 1 | ... | 7 | ... | 6 | 3 | ... | 1 | ... | 4 | ... | 12 | ... | ... | 9 | 12 | 4 | 16 | 22 | ... | ... | ... |
| *Kon:* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rate | 41 | 49 | ... | 63 | 61 | 63 | 57 | 58 | 63 | ... | ... | ... | 60 | 61 | 64 | 64 | 61 | ... | 73 | ... | ... | 63 | 63 | 65 | 69 | 46 | 44 | 46 | 48 | [1]44 | 48 | ... |
| P. ct. change[2] | ... | ... | ... | 29 | 25 | 29 | 16 | 18 | 29 | ... | ... | ... | 22 | 25 | 31 | 31 | 25 | ... | 49 | ... | ... | 29 | 29 | 33 | 41 | −6 | −10 | −6 | −2 | ... | ... | ... |
| *Gar:* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rate | 45 | 43 | 44 | 70 | 65 | 64 | 57 | 60 | 61 | ... | 61 | 59 | 63 | 61 | ... | ... | ... | 63 | 63 | ... | 62 | 64 | 64 | 64 | 63 | 46 | 46 | 47 | 54 | 42 | 39 | ... |
| P. ct. change | ... | ... | ... | 59 | 48 | 45 | 30 | 36 | 39 | ... | 39 | 34 | 43 | 39 | ... | ... | ... | 43 | 43 | ... | 41 | 45 | 45 | 45 | 43 | 5 | 5 | 7 | 23 | ... | ... | ... |
| *Gul:* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rate | 57 | 71 | 67 | 80 | 75 | 76 | 75 | ... | 76 | ... | 76 | ... | ... | ... | 76 | 76 | ... | 76 | ... | 79 | ... | 78 | 77 | ... | 78 | 56 | 63 | 60 | 65 | 57 | ... | 52 |
| P. ct. change | ... | ... | ... | 19 | 12 | 13 | 12 | ... | 13 | ... | 13 | ... | ... | ... | 13 | 13 | ... | 13 | ... | 18 | ... | 16 | 15 | ... | 16 | −16 | −6 | −10 | −3 | ... | ... | ... |
| *Mon:* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rate | 49 | 56 | 61 | 73 | 71 | 70 | 72 | 72 | 71 | ... | 73 | ... | 72 | ... | 76 | 75 | ... | 74 | 74 | 78 | 79 | 82 | 79 | 76 | ... | 63 | 64 | 63 | 60 | 55 | 56 | ... |
| P. ct. change | ... | ... | ... | 20 | 16 | 15 | 18 | 18 | 16 | ... | 20 | ... | 18 | ... | 25 | 23 | ... | 21 | 21 | 28 | 30 | 34 | 30 | 25 | ... | 3 | 5 | 3 | −2 | ... | ... | ... |
| *Moy:* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rate | 45 | ... | 48 | 59 | 63 | 62 | 60 | 66 | 62 | 64 | 63 | ... | 64 | ... | 71 | 63 | 64 | 62 | ... | 67 | 63 | 65 | 65 | 68 | 67 | 57 | 51 | 51 | 54 | 43 | ... | 49 |
| P. ct. change | ... | ... | ... | 23 | 31 | 29 | 25 | 38 | 29 | 33 | 31 | ... | 33 | ... | 48 | 31 | 33 | 29 | ... | 40 | 31 | 35 | 35 | 42 | 40 | 19 | 6 | 6 | 13 | ... | ... | ... |
| *Pea:* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rate | 47 | ... | 63 | 65 | 64 | 61 | 63 | 61 | 65 | 63 | 62 | 63 | 63 | 63 | 63 | 64 | 62 | 62 | 64 | 65 | 63 | 62 | 62 | 64 | 69 | 54 | 50 | 49 | 52 | 47 | 46 | ... |
| P. ct. change | ... | ... | ... | 3 | 2 | −3 | 0 | −3 | 3 | 0 | −2 | 0 | 0 | 0 | 0 | 2 | −2 | −2 | 2 | 3 | 0 | −2 | −2 | −2 | 10 | −14 | −21 | −22 | −17 | ... | ... | ... |
| *Pec:* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rate | 42 | 52 | 55 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | [1]47 | 52 | ... |
| *Tom:* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rate | 72 | 84 | 76 | 87 | 85 | 80 | 78 | 82 | 86 | ... | 85 | ... | 87 | ... | 87 | 85 | ... | 85 | ... | 88 | ... | 90 | 90 | ... | 92 | 85 | 81 | 85 | 90 | [1]62 | 66 | ... |
| P. ct. change | ... | ... | ... | 14 | 12 | 5 | 3 | 8 | 13 | ... | 12 | ... | 14 | ... | 14 | 12 | ... | 12 | ... | 16 | ... | 18 | 18 | ... | 21 | 12 | 7 | 12 | 18 | ... | ... | ... |
| *Vea:* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rate | 49 | ... | 49 | ... | 59 | ... | 65 | ... | ... | ... | 60 | ... | 64 | ... | 63 | 61 | ... | 64 | ... | ... | ... | ... | ... | ... | ... | 60 | 54 | 55 | 57 | [1]47 | ... | 41 |
| P. ct. change | ... | ... | ... | ... | 20 | ... | 33 | ... | ... | ... | 22 | ... | 31 | ... | 29 | 25 | ... | 31 | ... | ... | ... | ... | ... | ... | ... | 22 | 10 | 12 | 16 | ... | ... | ... |
| Average | 52 | 63 | 60 | 72 | 68 | 68 | 67 | 68 | 69 | ... | ... | ... | ... | ... | 72 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 73 | 61 | 59 | 60 | 63 | 50 | 52 | |
| Per cent | ... | ... | ... | 20 | ... | ... | ... | ... | 15 | ... | ... | ... | ... | ... | 20 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 22 | ... | ... | ... | ... | ... | ... | ... |

[1]Rate at 5 minutes. [2]Based on rate standing outside chamber.

was but 1 beat higher than for 9 subjects at the end of 1 minute, and it is in harmony with the results found with Squad B on January 6 and January 28. During the first 30 seconds of standing following walking, the average pulse-rate fell 12 beats from the rate at 24 minutes, and varied but 1 or 2 beats during the 120 seconds of standing, thus indicating the quick response of the heart to the requirements of the body. This rate was practically the same as that found during the preliminary standing period. In this respect, Squad A differed from Squad B on January 28 when the pulse did not return to the preliminary standing rate, at least in the time covered by the observation. The pulse-rates counted after 2 minutes of sitting, *i. e.*, 4 minutes after walking ceased, show a further fall in rate of 13 beats. Taking for an average the rates at the fourth and fifth minutes, we find it to be 50 beats, or 4 per cent below the sitting pulse at the start of the experiment. By the end of 8 or 9 minutes of sitting, the pulse-rate had recovered and the average of 11 men was 52, or the same as the original sitting pulse.

In table 101 are given the pulse-rates of 5 normal subjects referred to on page 436. The pulse-rates for the sitting position, preliminary to walking, are the average counts taken each minute for the 10 minutes during which the subject sat, except for *E.L.F.* and *H.S.*, whose averages are from counts made for 6 and 7 minutes, respectively, of the 10 minutes of sitting. During the standing period, the average in each case is from counts taken each minute for 11 minutes. It is seen that the rate for *H.M.S.* remains very nearly uniform for the entire walking period at about 9 beats above the standing rate. While the data for *H.W.F.* are not so complete as for the others, they show a smaller initial change in the rate with greater variations during the period of walking. *E.L.F.* has a larger initial change than the others and this rate is maintained throughout the walking period on the whole rather uniformly. The rate of *T.M.C.* after the first minute shows a decided drop which is then maintained approximately 5 beats above the standing rate. The changes in the rate of *H.S.* are similar to those of *T.M.C.* for the first third of the period but show greater variations as the period progresses. The average increase in the pulse-rate from sitting to standing is 8 beats or 12 per cent of the sitting rate, and the increase due to walking 1 minute is 9 beats with a rate of 85 beats, or 12 per cent of the standing rate. During the succeeding 3 minutes, there was a fall to an average rate of 81 beats at the fourth minute and a subsequent increase to 85 beats by the sixth minute. The latter was the rate found at the end of the first minute and was maintained practically unchanged during the remainder of the walking period. The fall in the pulse-rate following the first minute of walking, and its subsequent recovery by the sixth minute is in character the same as with the two diet squads, though perhaps not so pronounced. There are

TABLE 101.—*Pulse-rate per minute preceding, during, and following walking in the treadmill chamber with percentage change from standing rate; 5 normal men.*

[1]Rate at 7 minutes. [2]Includes *E. L. F.* at 5 minutes.

TABLE 102.—*Comparison of the average pulse-rates of a group of 5 normal men and Squad B normal with Squad B 20-day and Squad A 120-day diet, while sitting, standing and walking, and standing and sitting after walking.*

[1]At 8 minutes. [2]At 7 minutes. [3]Average of 8–9 minutes.

after 120 days of low diet and the five normals were both at the average preliminary sitting rate after 8 minutes, while Squad B normal and Squad B 20-day vary from 5 beats below to 1 beat above the preliminary sitting rate.

From the data given in tables 138, 140, and 142, the percentage change in the metabolism between standing and walking as shown by the heat output may be computed. This corresponds to 215 per cent for Squad B normal, 239 per cent for Squad B 20-day diet, and 215 per cent for Squad A 120-day diet, or the increase in the metabolism with walking 70 meters per minute as compared with the metabolism with standing is approximately alike for the normal and diet squads at about 220 per cent. In contrast with this large percentage increase in the metabolism it is seen from table 102 that the pulse-rate increases more nearly 25 per cent for the diet squads and 10 per cent for the normal squads. This contrast between the percentage changes in the pulse-rate and the metabolism which has been noted before in connection with a series of walking experiments and which differ from those found during muscular work on an ergometer[1], will be discussed

[1]Benedict and Murschhauser, Carnegie Inst. Wash. Pub. No. 231, 1915, p. 85.

TABLE 103.—*Pulse-rate before and after work on bicycle ergometer—Squad A, subjects in lying position, with food. November 23, 1917.*

[1] Average number of minutes taken to return to normal, 10.1.

TABLE 104.—*Comparison of pulse-rates before and after work on bicycle ergometer with reduced diet and with unrestricted diet—Squad A.*

[Subjects in lying position, with food.]

| Subject and dates. | Body-weight without clothing. | Pulse-rate 1 minute before work. | Pulse-rate in successive minutes after work ceased. | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1st. | 2d. | 3d. | 4th. | 5th. | 6th. | 7th. | 8th. | 9th. | 10th. | 11th. | 12th. | 13th. | 14th. | 15th. | 16th. | 17th. | 18th. | 19th. | 20th. |
| *Bro.* | | | | | | | | | | | | | | | | | | | | | | |
| Reduced diet: | *kg.* | | | | | | | | | | | | | | | | | | | | | |
| Jan. 31 | 54.8 | 48 | 84 | 52 | 48 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Unrestricted diet:[1] | | | | | | | | | | | | | | | | | | | | | | |
| Feb. 8 | 58.0 | 81 | 120 | 88 | 88 | 88 | 84 | 84 | 81 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 11 | 60.0 | 76 | 120 | 81 | 85 | 84 | 80 | 84 | 81 | 82 | 85 | 84 | 84 | 76 | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 15 | 62.5 | 76 | 112 | 85 | 84 | 80 | 85 | 88 | 76 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 18 | 61.0 | 73 | 105 | 77 | 81 | 85 | 88 | 84 | 80 | 80 | 73 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Can.* | | | | | | | | | | | | | | | | | | | | | | |
| Reduced diet: | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 31 | 70.5 | 46 | 81 | 53 | 46 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Unrestricted diet:[1] | | | | | | | | | | | | | | | | | | | | | | |
| Feb. 8 | 75.0 | 62 | 109 | 77 | 74 | 70 | 68 | 70 | 74 | 72 | 72 | 76 | 72 | 70 | 69 | 69 | 70 | 69 | 69 | 62 | ... | ... |
| Feb. 11 | 74.8 | 74 | 120 | 88 | 77 | 80 | 80 | 82 | 81 | 78 | 81 | 80 | 78 | 74 | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 18 | 77.0 | 66 | 108 | 72 | 69 | 66 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Kon.* | | | | | | | | | | | | | | | | | | | | | | |
| Reduced diet: | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 31 | 62.5 | 45 | 86 | 65 | 50 | 53 | 55 | 54 | 49 | 50 | 49 | 45 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Unrestricted diet:[1] | | | | | | | | | | | | | | | | | | | | | | |
| Feb. 8 | 67.3 | 82 | 122 | 103 | 100 | 97 | 92 | 92 | 88 | 88 | 90 | 88 | 86 | 86 | 88 | 95 | 90 | 90 | 89 | 85 | 89 | [2]85 |
| *Gar.* | | | | | | | | | | | | | | | | | | | | | | |
| Reduced diet: | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 31 | 64.3 | 58 | 112 | 73 | 65 | 65 | 66 | 58 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Unrestricted diet:[1] | | | | | | | | | | | | | | | | | | | | | | |
| Feb. 8 | 67.0 | 66 | 128 | 85 | 80 | 76 | 77 | 78 | 78 | 78 | 77 | 80 | 77 | 78 | 78 | 77 | 76 | 80 | 77 | 74 | ... | ... |
| Feb. 11 | 68.5 | 71 | 126 | 88 | 78 | 73 | 76 | 74 | 73 | 76 | 77 | 74 | 74 | 77 | 74 | 71 | ... | ... | ... | ... | ... | ... |
| Feb. 15 | 69.8 | 70 | 126 | 80 | 76 | 76 | 74 | 74 | 73 | 74 | 77 | 70 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 18 | 70.5 | 66 | 116 | 75 | 69 | 66 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Gul.* | | | | | | | | | | | | | | | | | | | | | | |
| Reduced diet: | | | | | | | | | | | | | | | | | | | | | | |
| [illegible] | [illegible] | [illegible] | 93 | 72 | 53 | 49 | 46 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unrestricted diet:[1] | | | | | | | | | | | | | | | | | | | | | | |
| Feb. 8 | 64.5 | 80 | 132 | 96 | 93 | 89 | 88 | 88 | 85 | 86 | 86 | 82 | 80 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 11 | 66.0 | 78 | 124 | 93 | 88 | 88 | 85 | 85 | 85 | 84 | 78 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 15 | 65.8 | 72 | 124 | 88 | 85 | 81 | 92 | 81 | 80 | 77 | 76 | 80 | 72 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 18 | 68.5 | 80 | 136 | 105 | 100 | 97 | 93 | 88 | 92 | 88 | 86 | 80 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Mon.* | | | | | | | | | | | | | | | | | | | | | | |
| Reduced diet: | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 31 | 60.3 | 57 | 93 | 73 | 65 | 65 | 64 | 62 | 66 | 67 | 63 | 61 | 57 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Unrestricted diet:[1] | | | | | | | | | | | | | | | | | | | | | | |
| Feb. 8 | 65.0 | 82 | 132 | 105 | 100 | 97 | 95 | 93 | 92 | 90 | 86 | 84 | 82 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 11 | 65.5 | 88 | 128 | 104 | 96 | 96 | 93 | 93 | 97 | 92 | 93 | 92 | 93 | 92 | 88 | ... | ... | ... | ... | ... | ... | ... |
| Feb. 15 | 67.0 | 85 | 128 | 108 | 104 | 101 | 95 | 96 | 92 | 96 | 93 | 93 | 85 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 18 | 67.3 | 80 | 122 | 101 | 96 | 96 | 92 | 92 | 93 | 89 | 84 | 88 | 80 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Moy.* | | | | | | | | | | | | | | | | | | | | | | |
| Reduced diet: | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 31 | 57.3 | 57 | 109 | 80 | 70 | 65 | 66 | 64 | 62 | 63 | 61 | 61 | 72 | 57 | ... | ... | ... | ... | ... | ... | ... | ... |
| Unrestricted diet:[1] | | | | | | | | | | | | | | | | | | | | | | |
| Feb. 8 | 63.5 | 77 | 124 | 96 | 85 | 88 | 85 | 82 | 81 | 77 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 11 | 62.0 | 76 | 128 | 93 | 84 | 84 | 84 | 80 | 82 | 81 | 85 | 81 | 81 | 81 | 81 | 78 | 81 | 76 | ... | ... | ... | ... |
| Feb. 15 | 65.0 | 77 | 118 | 89 | 80 | 81 | 84 | 84 | 81 | 84 | 77 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 18 | 66.0 | 76 | 128 | 80 | 80 | 85 | 80 | 80 | 79 | 78 | 76 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Pea.* | | | | | | | | | | | | | | | | | | | | | | |
| Reduced diet: | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 31 | 61.5 | 42 | 96 | 57 | 44 | 42 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Unrestricted diet:[1] | | | | | | | | | | | | | | | | | | | | | | |
| Feb. 15 | 69.8 | 80 | 120 | 84 | 84 | 80 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 18 | 70.3 | 84 | 132 | 88 | 84 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Pec.* | | | | | | | | | | | | | | | | | | | | | | |
| Reduced diet: | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 31 | 59.0 | 42 | 76 | 53 | 42 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Unrestricted diet:[1] | | | | | | | | | | | | | | | | | | | | | | |
| Feb. 8 | 60.0 | 60 | 100 | 69 | 60 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 11 | 63.5 | 74 | 109 | 86 | 80 | 80 | 82 | 77 | 77 | 80 | 74 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 15 | 64.5 | 80 | 109 | 82 | 80 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 18 | 66.0 | 88 | 122 | 101 | 97 | 96 | 100 | 93 | 92 | 92 | 92 | 88 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Vea.* | | | | | | | | | | | | | | | | | | | | | | |
| Reduced diet: | | | | | | | | | | | | | | | | | | | | | | |
| Jan. 31 | 59.5 | 37 | 89 | 44 | 40 | 40 | 37 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Unrestricted diet:[1] | | | | | | | | | | | | | | | | | | | | | | |
| Feb. 8 | 59.8 | 53 | 90 | 60 | 53 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 11 | 62.0 | 76 | 109 | 88 | 84 | 81 | 81 | 81 | 81 | 80 | 80 | 76 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 15 | 65.3 | 86 | 124 | 100 | 93 | 93 | 92 | 89 | 86 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Feb. 18 | 65.5 | 74 | 116 | 93 | 85 | 90 | 86 | 77 | 84 | 74 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

[1] Unrestricted diet began with breakfast, Feb. 3.

[2] *Kon* showed a pulse-rate of 82 at the 21st minute.

TABLE 105.—*Time required for pulse-rate to return to normal after work on bicycle ergometer—Squad A, subjects in lying position, with food.*

| Date. | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pea. | Pec. | Spe. | Tom. | Vea. | Av. for squad.[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. Reduced diet: | *min.* | *min.* | *min.* | *min.* | *min.* | *min.* | *min.* | *min.* | *min.* | *min.* | *min.* | *min.* | *min.* |
| Oct. 19 | 7 | 4 | ........ | 10 | 12 | 20 | 9 | 4 | 8 | 8 | 7 | 8 | 9.1 |
| 22 | 3 | 5 | ........ | 7 | 15 | 14 | 10 | 4 | 6 | 8 | 17 | 4 | 7.6 |
| 26 | 3 | 3 | ........ | 3 | 13 | 5 | 4 | 6 | 4 | [2]20 | [2]20 | 4 | 5.0 |
| 29 | 6 | 4 | 8 | [2]20 | 11 | 18 | 6 | 3 | 4 | 17 | 14 | 4 | 8.4+ |
| Nov. 2 | ........ | 3 | ........ | [2]20 | [2]20 | 5 | 7 | 4 | 3 | 8 | 12 | 3 | 8.1+ |
| 5 | ........ | 3 | 6 | [2]20 | 9 | 13 | 18 | 5 | 4 | 2 | 16 | 3 | 9.0+ |
| 9 | 13 | 4 | 10 | 8 | 16 | 14 | 12 | 6 | 6 | 11 | [2]20 | 3 | 9.2 |
| 12 | 18 | 3 | 11 | 16 | 7 | 18 | [2]20 | 7 | 4 | 9 | 20 | 3 | 10.7+ |
| 16 | 14 | ........ | 13 | 16 | 8 | [2]20 | [2]20 | 8 | ........ | 10 | [2]20 | 4 | 12.9+ |
| 19 | [2]20 | 17 | ........ | 3 | 5 | 12 | 15 | 5 | 6 | 6 | ........ | 3 | 9.6+ |
| 23 | 20 | 16 | 3 | 3 | 5 | 7 | 19 | [2]20 | 5 | 4 | 18 | 4 | 10.2+ |
| 26 | 4 | 12 | [2]20 | ........ | [2]20 | 13 | 15 | 6 | 4 | 3 | [2]20 | 3 | 10.8+ |
| Dec. 3 | 3 | 3 | ........ | ........ | ........ | 18 | [2]20 | 4 | 6 | [2]20 | [2]20 | 3 | 8.1+ |
| 7 | 6 | 3 | [2]20 | 4 | 3 | 18 | [2]20 | 7 | 3 | 9 | 17 | 7 | 9.1+ |
| 10 | 10 | 2 | [2]20 | 3 | 8 | 11 | 9 | 13 | 3 | 11 | 10 | 6 | 8.5+ |
| 14 | [2]20 | ........ | ........ | 3 | 3 | 18 | [2]20 | 3 | 3 | ........ | [2]20 | 4 | 9.3+ |
| 17 | 7 | 3 | 4 | 3 | 16 | 20 | 17 | 7 | 3 | ........ | 16 | 3 | 8.3 |
| 1918. | | | | | | | | | | | | | |
| Jan. 7 | ........ | ........ | ........ | 4 | ........ | ........ | 9 | 4 | ........ | ........ | ........ | ........ | ........ |
| 11 | 5 | 3 | ........ | 5 | 3 | 4 | 11 | 3 | 8 | ........ | ........ | 3 | 5.0 |
| 14 | ........ | 2 | [2]20 | 3 | 6 | 7 | 14 | 4 | 3 | ........ | ........ | 3 | 6.9+ |
| 18 | 3 | 10 | 5 | ........ | 7 | 8 | 10 | 9 | 3 | ........ | ........ | 5 | 6.7 |
| 21 | 3 | 3 | [2]20 | 3 | 3 | 9 | 4 | 3 | 3 | ........ | ........ | 3 | 5.4+ |
| 28 | 3 | 2 | ........ | 4 | 10 | 17 | 3 | 2 | 2 | ........ | ........ | 3 | 5.1 |
| 31 | 3 | 3 | 10 | 6 | 5 | 11 | 12 | 4 | 3 | ........ | ........ | 5 | 6.2 |
| Av | 8.6+ | 5.1 | 12.1+ | 7.8+ | 9.3+ | 13.0+ | 12.7+ | 5.9+ | 4.3 | 9.7+ | 16.7+ | 4.0 | 8.3+ |
| Unrestricted diet: | | | | | | | | | | | | | |
| Feb. 8 | 7 | 18 | [2]20 | [2]20 | 11 | 11 | 8 | ........ | 3 | ........ | ........ | 3 | 11.2+ |
| 11 | 12 | 12 | ........ | 14 | 9 | 13 | 15 | ........ | 9 | ........ | ........ | 10 | 11.8 |
| 15 | 7 | ........ | ........ | 10 | 11 | 11 | 9 | 4 | 3 | ........ | ........ | 7 | 7.7 |
| 18 | 9 | 4 | ........ | 4 | 10 | 11 | 9 | 3 | 10 | ........ | ........ | 8 | 7.5 |
| Av | 8.8 | 11.3 | 20.0+ | 12.0+ | 10.3 | 11.5 | 10.3 | 3.5 | 6.3 | ........ | ........ | 7.0 | 10.1+ |

[1] These averages do not include the values for *Spe* and *Tom.*

[2] More than 20 minutes required for pulse-rate to return to normal; the averages which include these records are indicated by the plus sign.

TABLE 106.—*Pulse-rate and percentage increase in pulse-rate following work on bicycle ergometer—Squad A, subjects in lying position, with food.*

| Date. | Bro. | | | Can. | | | Kon. | | | Gar. | | | Gul. | | | Mon. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 minute before work. | 1 minute after work. | Percentage increase. | 1 minute before work. | 1 minute after work. | Percentage increase. | 1 minute before work. | 1 minute after work. | Percentage increase. | 1 minute before work. | 1 minute after work. | Percentage increase. | 1 minute before work. | 1 minute after work. | Percentage increase. | 1 minute before work. | 1 minute after work. | Percentage increase. |
| 1917. Reduced diet: | | | | | | | | | | | | | | | | | | |
| Oct. 19 | 64 | 96 | 50 | 68 | 108 | 59 | ... | ... | ... | 52 | 124 | 138 | 68 | 120 | 76 | 64 | 112 | 75 |
| 22 | 64 | 92 | 44 | 52 | 96 | 85 | ... | ... | ... | 56 | 116 | 107 | 62 | 120 | 94 | 68 | 108 | 59 |
| 26 | 60 | 100 | 67 | 68 | 116 | 71 | ... | ... | ... | 52 | 92 | 77 | 68 | 112 | 65 | 68 | 120 | 76 |
| 29 | 58 | 92 | 59 | 51 | 100 | 96 | 56 | 101 | 80 | 44 | 97 | 120 | 58 | 100 | 72 | 64 | 116 | 81 |
| Nov. 2 | ... | ... | ... | 48 | 84 | 75 | ... | ... | ... | 40 | 95 | 138 | 57 | 101 | 77 | 65 | 101 | 55 |
| 5 | ... | ... | ... | 53 | 74 | 40 | 64 | 108 | 69 | 48 | 107 | 123 | 51 | 90 | 76 | 58 | 105 | 81 |
| 9 | 56 | 103 | 84 | 50 | 73 | 46 | 41 | 107 | 161 | 45 | 104 | 131 | 47 | 93 | 98 | 53 | 112 | 111 |
| 12 | 58 | 104 | 79 | 48 | 76 | 58 | 42 | 92 | 119 | 39 | 90 | 131 | 43 | 88 | 105 | 51 | 99 | 94 |
| 16 | 60 | 119 | 98 | ... | ... | ... | 36 | 85 | 136 | 38 | 95 | 150 | 44 | 85 | 93 | 49 | 96 | 96 |
| 19 | 45 | 85 | 89 | 49 | 85 | 73 | ... | ... | ... | 50 | 95 | 90 | 53 | 92 | 74 | 65 | 107 | 65 |
| 23 | 53 | 93 | 75 | 45 | 81 | 80 | 37 | 76 | 105 | 53 | 103 | 94 | 42 | 84 | 100 | 57 | 101 | 77 |
| 26 | 56 | 81 | 45 | 46 | 81 | 76 | 36 | 76 | 111 | ... | ... | ... | 45 | 95 | 111 | 58 | 103 | 78 |
| Dec. 3 | 51 | 90 | 76 | 53 | 85 | 60 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 64 | 114 | 78 |
| 7 | 62 | 101 | 63 | 53 | 84 | 58 | 42 | 97 | 131 | 42 | 92 | 119 | 53 | 85 | 60 | 56 | 109 | 95 |
| 10 | 63 | 114 | 81 | 60 | 89 | 48 | 49 | 107 | 118 | 49 | 93 | 90 | 53 | 95 | 79 | 74 | 126 | 70 |
| 14 | 58 | 104 | 79 | ... | ... | ... | ... | ... | ... | 47 | 100 | 113 | 52 | 85 | 63 | 69 | 122 | 77 |
| 17 | 62 | 108 | 74 | 50 | 79 | 58 | 45 | 100 | 122 | 49 | 99 | 102 | 53 | 100 | 89 | 63 | 112 | 78 |
| 1918. | | | | | | | | | | | | | | | | | | |
| Jan. 7 | ... | ... | ... | ... | ... | ... | | | | 57 | 124 | 118 | ... | ... | ... | ... | ... | ... |
| 11 | 58 | 93 | 60 | 54 | 93 | 72 | ... | ... | ... | 53 | 112 | 111 | 58 | 99 | 71 | 60 | 96 | 60 |
| 14 | ... | ... | ... | 53 | 85 | 60 | 54 | 100 | 85 | 49 | 100 | 104 | 53 | 101 | 91 | 66 | 97 | 47 |
| 18 | 58 | 84 | 45 | 46 | 89 | 93 | 46 | 101 | 120 | ... | ... | ... | 52 | 112 | 115 | 62 | 109 | 76 |
| 21 | 51 | 77 | 51 | 42 | 80 | 90 | 42 | 93 | 121 | 45 | 92 | 104 | 49 | 99 | 102 | 56 | 103 | 84 |
| 28 | 49 | 86 | 76 | 49 | 73 | 49 | ... | ... | ... | 42 | 88 | 110 | 44 | 92 | 109 | 54 | 100 | 85 |
| 31 | 48 | 84 | 75 | 46 | 81 | 76 | 45 | 86 | 91 | 58 | 112 | 93 | 46 | 93 | 102 | 57 | 93 | 63 |
| Unrestricted diet: | | | | | | | | | | | | | | | | | | |
| Feb. 8 | 81 | 120 | 48 | 62 | 109 | 76 | 82 | 122 | 49 | 66 | 128 | 94 | 80 | 132 | 65 | 82 | 132 | 61 |
| 11 | 76 | 120 | 58 | 74 | 120 | 62 | ... | ... | ... | 71 | 126 | 77 | 78 | 124 | 59 | 88 | 128 | 45 |
| 15 | 76 | 112 | 47 | ... | ... | ... | ... | ... | ... | 70 | 126 | 80 | 72 | 124 | 72 | 85 | 128 | 51 |
| 18 | 73 | 105 | 44 | 66 | 108 | 64 | ... | ... | ... | 66 | 116 | 76 | 80 | 136 | 70 | 80 | 122 | 53 |

| Date. | Moy. | | | Pea. | | | Pec. | | | Spe. | | | Tom. | | | Vea. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 minute before work. | 1 minute after work. | Percentage increase. | 1 minute before work. | 1 minute after work. | Percentage increase. | 1 minute before work. | 1 minute after work. | Percentage increase. | 1 minute before work. | 1 minute after work. | Percentage increase. | 1 minute before work. | 1 minute after work. | Percentage increase. | 1 minute before work. | 1 minute after work. | Percentage increase. |
| 1917. | | | | | | | | | | | | | | | | | | |
| Reduced diet: | | | | | | | | | | | | | | | | | | |
| Oct. 19 | 62 | 120 | 94 | 48 | 84 | 75 | 80 | 128 | 60 | 60 | 108 | 80 | 72 | 108 | 50 | 60 | 100 | 67 |
| 22 | 60 | 108 | 80 | 42 | 84 | 100 | 52 | 100 | 92 | 60 | 104 | 73 | 64 | 132 | 106 | 64 | 100 | 56 |
| 26 | 62 | 116 | 87 | 48 | 100 | 108 | 52 | 88 | 69 | 72 | 112 | 56 | 68 | 128 | 88 | 64 | 108 | 69 |
| 29 | 48 | 100 | 108 | 42 | 81 | 93 | 47 | 84 | 79 | 52 | 100 | 92 | 70 | 124 | 77 | 69 | 104 | 51 |
| Nov. 2 | 70 | 128 | 83 | 41 | 82 | 100 | 40 | 73 | 83 | 61 | 99 | 62 | 61 | 118 | 93 | 66 | 103 | 56 |
| 5 | 43 | 100 | 133 | 44 | 84 | 91 | 41 | 74 | 80 | 53 | 86 | 62 | 58 | 120 | 107 | 66 | 108 | 64 |
| 9 | 49 | 115 | 135 | 41 | 85 | 107 | 37 | 78 | 111 | 45 | 79 | 76 | 56 | 123 | 120 | 58 | 95 | 64 |
| 12 | 40 | 99 | 147 | 36 | 91 | 153 | 38 | 83 | 118 | 58 | 105 | 81 | 60 | 122 | 103 | 64 | 104 | 63 |
| 16 | 41 | 107 | 161 | 34 | 76 | 124 | ...... | ...... | ...... | 69 | 114 | 65 | 59 | 132 | 124 | 38 | 72 | 89 |
| 19 | 36 | 96 | 167 | 39 | 84 | 115 | 34 | 76 | 124 | 46 | 83 | 80 | ...... | ...... | ...... | 45 | 90 | 100 |
| 23 | 41 | 116 | 183 | 40 | 89 | 123 | 36 | 65 | 81 | 53 | 92 | 74 | 60 | 118 | 97 | 40 | 72 | 80 |
| 26 | 38 | 107 | 182 | 38 | 85 | 124 | 41 | 81 | 98 | 61 | 100 | 64 | 67 | 132 | 97 | 42 | 84 | 100 |
| Dec. 3 | 45 | 101 | 124 | 42 | 85 | 102 | 47 | 77 | 64 | 56 | 108 | 93 | 78 | 144 | 85 | 50 | 96 | 92 |
| 7 | 43 | 112 | 160 | 36 | 77 | 114 | 42 | 81 | 93 | 53 | 88 | 66 | 58 | 109 | 88 | 35 | 69 | 97 |
| 10 | 53 | 120 | 126 | 42 | 97 | 131 | 41 | 80 | 95 | 58 | 105 | 81 | 63 | 122 | 94 | 41 | 84 | 105 |
| 14 | 45 | 108 | 140 | 40 | 81 | 103 | 48 | 92 | 92 | ...... | ...... | ...... | 62 | 128 | 106 | 36 | 72 | 100 |
| 17 | 49 | 116 | 137 | 42 | 96 | 129 | 47 | 81 | 72 | ...... | ...... | ...... | 63 | 116 | 84 | 37 | 70 | 89 |
| 1918. | | | | | | | | | | | | | | | | | | |
| Jan. 7 | 74 | 124 | 68 | 48 | 100 | 108 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 11 | 44 | 100 | 127 | 46 | 96 | 109 | 46 | 88 | 91 | ...... | ...... | ...... | ...... | ...... | ...... | 56 | 101 | 80 |
| 14 | 49 | 111 | 127 | 56 | 104 | 86 | 49 | 88 | 80 | ...... | ...... | ...... | ...... | ...... | ...... | 48 | 85 | 77 |
| 18 | 46 | 105 | 128 | 48 | 99 | 106 | 53 | 84 | 58 | ...... | ...... | ...... | ...... | ...... | ...... | 34 | 65 | 91 |
| 21 | 39 | 96 | 146 | 41 | 86 | 110 | 42 | 80 | 90 | ...... | ...... | ...... | ...... | ...... | ...... | 32 | 60 | 88 |
| 28 | 42 | 93 | 121 | 45 | 81 | 80 | 45 | 76 | 69 | ...... | ...... | ...... | ...... | ...... | ...... | 36 | 65 | 81 |
| 31 | 57 | 109 | 91 | 42 | 96 | 129 | 42 | 76 | 81 | ...... | ...... | ...... | ...... | ...... | ...... | 37 | 89 | 141 |
| Unrestricted diet: | | | | | | | | | | | | | | | | | | |
| Feb. 8 | 77 | 124 | 61 | ...... | ...... | ...... | 60 | 100 | 67 | ...... | ...... | ...... | ...... | ...... | ...... | 53 | 90 | 70 |
| 11 | 76 | 128 | 68 | ...... | ...... | ...... | 74 | 109 | 47 | ...... | ...... | ...... | ...... | ...... | ...... | 76 | 109 | 43 |
| 15 | 77 | 118 | 53 | 80 | 120 | 50 | 80 | 109 | 36 | ...... | ...... | ...... | ...... | ...... | ...... | 86 | 124 | 44 |
| 18 | 76 | 128 | 68 | 84 | 132 | 57 | 88 | 122 | 39 | ...... | ...... | ...... | ...... | ...... | ...... | 74 | 116 | 57 |

TABLE 107.—*Percentage increase in pulse-rate and time required to return to normal after work on bicycle ergometer—Squad B, subjects in lying position, with food*—continued.

[1]Pulse-rate was 72 at the end of 16 minutes; no further records obtained.

observations made with Squad A, in which the basal values with low diet obtained during January, when compared with those obtained during February with an unrestricted diet, showed a tendency for a more rapid return to normal of the pulse-rate following a definite amount of physical work.

### CONCLUSIONS REGARDING PULSE-RATE.

In this section we have endeavored to present as complete a picture as possible of the changes in pulse-rate level occasioned by the low diet with the accompanying change to a lower nutritional plane. We have presented data for the basal pulse-rate with the subjects in the lying position and with the subjects in the same position before riding the bicycle ergometer, with the subjects sitting and standing, and engaging in short periods of muscular exertion, also beginning to walk on the treadmill, during a prolonged period of walking, the transition following walking, and, finally, the recovery to the normal pulse-rate following a standard amount of work on the bicycle ergometer. The data have been presented analytically in each case and compared with the normal standard. This normal standard is rather fragmentary in the case of Squad A but fairly satisfactory for Squad B; in some cases there are other normals with which we could compare these low-diet pulse-rates.

It would appear as proved by the standard electrocardiograms that the lower pulse-rate characteristic of the low diet is not accompanied by any pathological changes but is a simple difference in the pulse-rate level between the condition of uncontrolled eating and the reduced diet. The actual values for the pulse-rate during rest are such as have never heretofore been observed with normal man, for a considerable number of men showed pulse-rates of 35 and below and one subject gave positive evidence of a rate of 29 on at least one day. Not only was the pulse-rate per minute very perceptibly reduced by the low diet, but the blood pressures have also been shown to be distinctly lower during the same period. (See p. 382.) These low blood pressures following diet restriction with both Squads A and B, taken in connection with the low pulse-rates, show clearly that the work of circulation of these men made a minimum demand on metabolic activity. We thus find here a most economically working heart, at least under normal conditions of rest.

During short periods of work, as in "chinning the bar" (p. 415), the percentage increase occasioned by this physical exercise was practically the same for normal men and for those on the low diet, that is, there was a simple change in pulse-level for the resting, working, and recuperation pulse with these short periods of work, *i. e.*, periods less than one-half minute in length. With the pulse during work, judged according to the standards which we have, it seems clear that the men on reduced diet showed a greater percentage increase, as, for example,

TABLE 108.—*Daily respiration rate—Squad A, post-absorptive and in lying position.*

TABLE 108.—*Daily respiration rate—Squad A, post-absorptive and in lying position*—continued.

month of January there is a tendency for the rate to be somewhat under this. With *Can* the rate is at first approximately 13 or thereabouts per minute, and during January it is on the average under 12 per minute. With *Kon* irregularity may be noted, particularly at the beginning, but unlike most of the subjects, his respiration rate shows a tendency to increase toward the end of the experiment. With *Gar* a respiration rate approximating 13 or 13.5 per minute at the start slows down to about 12.5 in January. With *Gul* considerable variation is seen at the start, with a tendency for a slight rise in

minute on the assumption that the regularity of breathing would be the same throughout the rest of the minute. In lieu of longer records it has been necessary to do this. The results obtained by the photographic method are therefore recorded only to whole numbers in table 110, in which the values are given for the respiration rate with the subject standing before walking and those found 1, 6, 12, 24, and 26 minutes after the walking began. A few records taken at other intervals are given in footnotes. Finally, a few values are recorded

TABLE 110.—*Respiration rate before, during, and after 24 minutes of level walking on a treadmill—Squads A and B.*

| Date and subject. | Respiration rate. | | | | | | |
|---|---|---|---|---|---|---|---|
| | Standing before walking. | Minutes after walking began. | | | | | Standing during first 30 seconds after walking ended. |
| | | 1[1] | 6 | 12 | 24 | 26 | |
| *Squad B.* | | | | | | | |
| Normal diet: | | | | | | | |
| Jan. 6, 1918. | | | | | | | |
| Har........ | ........ | 26 | 26 | 22 | 25 | ...... | ................ |
| How....... | 18 | 24 | 18 | 21 | 25 | ...... | ................ |
| Ham....... | ........ | ...... | 30 | 29 | 26 | ...... | ................ |
| Kim....... | ........ | 20 | 22 | 21 | 23 | ...... | ................ |
| Sch........ | 18 | ...... | 24 | ...... | 25 | ...... | ................ |
| Liv........ | ........ | 31 | 28 | 28 | 31 | ...... | ................ |
| Sne........ | 25 | 22 | 23 | 23 | ...... | ...... | ................ |
| Tho........ | ........ | 23 | 27 | 25 | ...... | ...... | ................ |
| Van........ | ........ | 25 | 25 | 23 | 20 | ...... | ................ |
| Wil........ | ........ | ...... | 27 | 26 | 27 | ...... | ................ |
| Reduced diet: | | | | | | | |
| Jan. 28, 1918. | | | | | | | |
| Fis........ | ........ | 22 | 24 | 21 | 20 | 27 | 20 |
| How....... | ........ | 17 | 20 | ...... | ...... | 22 | 18 |
| Ham....... | 18 | 22 | 27 | 27 | 28 | 24 | 23 |
| Kim....... | ........ | 22 | 17 | 18 | 22 | 23 | 17 |
| Sch........ | ........ | 23 | 25 | 23 | 26 | ...... | ................ |
| Liv........ | ........ | 26 | 25 | 25 | 28 | ...... | ................ |
| Sne........ | 18 | 26 | 29 | 26 | 31 | 26 | 23 |
| Wil........ | ........ | 20 | 23 | 26 | 25 | ...... | ................ |
| *Squad A.* | | | | | | | |
| Reduced diet: | | | | | | | |
| Feb. 3, 1918. | | | | | | | |
| Bro........ | ........ | 26 | 23 | 23 | 23 | 25 | 20 |
| Can........ | ........ | ...... | 21 | 19 | 21 | 24 | 20 |
| Kon........ | ........ | 26 | 26 | 26 | 28 | ...... | 20 |
| Gar........ | ........ | 18 | 20 | 21 | 22 | ...... | 17 |
| Gul[2]....... | 16 | 18 | 21 | 22 | 24 | 22 | 20 |
| Moy....... | 14 | 18 | 18 | 15 | 21 | 23 | 13 |
| Pea........ | 20 | ...... | 27 | 28 | 29 | ...... | 18 |
| Pec........ | 17 | 21 | 22 | ...... | ...... | ...... | 20 |
| Tom....... | 14 | 17 | 18 | 19 | 17 | 20 | 17 |
| Vea[3]....... | 18 | 20 | 21 | 23 | 24 | 24 | 17 |

[1] The respiration rates for January 28 and February 3 were recorded during the first minute.

[2] The respiration rate of *Gul* after he had walked 4 minutes was 21; after 8 minutes, 27; after 14 minutes, 23; after 16 minutes, 22; after 18 minutes, 24; after 20 minutes, 22; after 22 minutes, 23.

[3] The respiration rate of *Vea* after he had walked 2 minutes was 23; after 4 minutes, 22; after 10 minutes, 24; after 14 minutes, 24; after 18 minutes, 24; after 20 minutes, 24; after 22 minutes, 25.

18 to 24 at the end of 1 and 6 minutes, respectively, while with *Sne* the prewalking respiration rate of 25 fell immediately after the beginning of walking to 22 and continued at 23 for the remainder of the test, a condition exactly opposite that reported with *Sch*. While the data are too few for generalization as to the change from the standing position to walking, the successive records obtained during walking are fairly numerous and show that there was no tendency for the respiration rate either to decrease or to increase as the test proceeded, although there were slight variations. On January 6 the respiration rate with the subject standing after walking was not obtained for any of the men.

Squad B was at this time on normal diet; hence the only conclusion that can be drawn is that the respiratory rate of the subjects inside the respiration chamber is practically unaltered by walking during the short period of 24 minutes, and that the carbon-dioxide increment inside the chamber had no measurable effect upon the respiration rate. This is perhaps the most important point to be noted from this particular test and indicates again that this squad is a true control for the subsequent test made with Squad A, as well as the test with Squad B after the men had been put on low diet. Thus it may be fairly assumed that an increment in carbon dioxide may be ruled out as a factor affecting respiration rate—at least the percentage of carbon dioxide with which we deal here.

On January 28 a second series of walking tests was made with Squad B at the Laboratory during which the respiration rate was counted. An examination of the data given in table 110 shows that here again we were particularly unfortunate in not securing a large number of counts before and after walking. Even a larger number of these records were illegible than in the first test and can not be recorded with any degree of accuracy. The 2 subjects with whom prewalking values were obtained showed an increment due to walking. Of particular significance is the apparent increment in the case of *Sne*, who went from 18 counts to 26 during the first minute of walking. After the first minute the rate rose to 29 per minute. The prewalking value of 18 was based upon a count of only three respiratory cycles and is thus somewhat uncertain. Consequently the evidence is by no means clear from these data that under these conditions walking results in an increased respiration rate. With five of our subjects we have records for standing after walking. In all five cases we find a material drop in respiration rate following the last record obtained for the walking. This fall is as much as 7 respirations in the case of *Fis* and with the other men ranges from 1 to 6.

From the beginning to the end of walking there is an increase with *Fis* of 5 respirations; with *Ham* 6; and with *Kim* 1. With all other subjects except *Sne*, the records are incomplete, but the evidence points to a tendency for a slight increase in the respiration rate as the walking

dioxide output, one can, assuming a dead space, also compute the carbon-dioxide tension in the alveolar air. In addition to these data we determined directly in a large number of cases the alveolar carbon-dioxide tension by a special technique. (See p. 79.) All of these values are recorded, together with certain other respiratory figures, in table 111.

The data for the total ventilation of the lungs per minute are recorded in the first two columns of the table, the first column giving the ventilation as actually observed from readings of the spirometer, and the second, the same data reduced to 0° C. and 760 mm. pressure.

The actual number of observations made of the total ventilation of the lungs prior to the reduction in diet are very few, only *Can* and *Gar* showing more than one value. The data for October 5 or subsequent thereto were obtained after the reduction in diet began. An inspection of the figures in both columns *a* and *b* shows a distinct tendency for the total ventilation of the lungs, both observed and reduced, to decrease somewhat with the length of time, although not necessarily in direct proportion to it. As a matter of fact, for the most part high values were found only in the first three observations, and but occasionally thereafter. In nearly every case after the first two weeks in October, a high ventilation of the lungs was accompanied by a large oxygen consumption. For example, with *Gar*, after a long series of values for ventilation per minute of 4.5 liters or under (see second column), we find on January 10, 14, and 18 three high values of practically 5 liters or over. These were all accompanied by a distinct increase in the oxygen consumption. The total metabolism is thus actually increased and there is an increased ventilation of the lungs to bring away the excess formation of the carbon dioxide. In general, there is a clear tendency for a decrease in the total ventilation of the lungs with a reduction in diet.

### VOLUME PER RESPIRATION.

As stated in the preceding section, the respiration rate per minute showed a tendency to decrease; the volume per respiration has therefore an interest. These volumes are recorded in the last column of table 111. Although these volumes show in a number of instances a slight tendency to decrease, they do not on the whole indicate a profound effect of the low diet. Certain cases, particularly *Vea* and *Gul*, show a tendency towards a pronounced reduction in volume per respiration. As a matter of fact, the values for *Gul* range from 634 c.c. on October 1 and 20 to as low as 399 c.c. on January 21, this being by far the widest difference noted with any of the subjects. *Vea* shows a range from 496 c.c. on October 8 to 381 c.c. on November 5.

In general, however, the slight decrease in the respiration rate which was noted as the research progressed, accompanied by a similar

TABLE 111.—*Ventilation of lungs and alveolar $CO_2$ tension in valve-apparatus experiments; subjects postabsorptive and in lying position—Squad A.*

| Subject and date. | Per minute. (a) Ventilation of lungs (observed). | Per minute. (b) Ventilation of lungs (reduced). | Per minute. (c) Carbon dioxide. | Per minute. (d) Oxygen. | (e) Respiratory quotient. | (f) Alveolar $CO_2$ tension (determined). | (g) Alveolar $CO_2$ tension (calculated). | Ventilation (observed) per minute per mm. $CO_2$ tension.[1] (h) From calculated $CO_2$ tension (a÷g). | Ventilation (observed) per minute per mm. $CO_2$ tension.[1] (i) From determined $CO_2$ tension (a÷f). | (j) Respiration rate per minute. | (k) Volume per respiration.[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Bro.* | *liters.* | *liters.* | *c.c.* | *c.c.* | | *mm.Hg.* | *mm.Hg.* | *c.c.* | *c.c.* | | *c.c.* |
| Sept. 29 | 4.42 | 3.99 | 149 | 215 | 0.70 | ........ | 45.0 | 98.2 | ........ | 11.8 | 413 |
| Oct. 5 | 4.89 | 4.44 | 176 | 210 | .84 | ........ | 44.3 | 110.4 | ........ | 11.6 | 466 |
| 11 | 4.58 | 4.16 | 148 | 201 | .74 | ........ | 47.1 | 97.2 | ........ | 13.7 | 368 |
| 16 | 4.23 | 3.80 | 143 | 190 | .75 | ........ | 48.5 | 87.2 | ........ | 12.2 | 380 |
| 26 | 4.27 | 3.86 | 142 | 194 | .74 | ........ | 49.0 | 87.1 | ........ | 12.8 | 365 |
| Nov. 8 | 4.20 | 3.79 | 140 | 187 | .75 | 44.9 | 47.6 | 88.2 | 93.5 | 12.1 | 379 |
| 15 | 3.92 | 3.53 | 144 | 187 | .77 | 44.9 | 52.9 | 74.2 | 87.3 | 11.4 | 377 |
| 21 | 4.11 | 3.68 | 138 | 184 | .75 | 47.0 | 49.5 | 83.0 | 87.4 | 12.3 | 367 |
| Dec. 8 | 5.01 | 4.60 | 140 | 186 | .75 | 46.6 | 35.2 | 142.3 | 107.5 | 12.5 | 443 |
| 15 | 4.25 | 3.87 | 137 | 177 | .77 | 47.8 | 45.1 | 94.2 | 88.9 | 12.2 | 384 |
| 18 | 4.03 | 3.76 | 138 | 176 | .78 | 48.2 | 48.6 | 82.9 | 83.6 | 12.1 | 368 |
| Jan. 11 | 4.61 | 4.19 | 147 | 195 | .75 | 47.2 | 43.5 | 106.0 | 97.7 | 12.9 | 398 |
| 15 | 3.98 | 3.57 | 142 | 178 | .80 | 45.2 | 50.5 | 78.8 | 88.1 | 11.5 | 384 |
| 19 | 4.18 | 3.75 | 136 | 177 | .77 | 45.4 | 46.9 | 89.1 | 92.1 | 12.2 | 377 |
| 23 | 3.90 | 3.48 | 126 | 165 | .76 | 48.4 | 48.2 | 80.9 | 80.6 | 11.8 | 364 |
| 26 | 4.17 | 3.78 | 129 | 165 | .78 | 48.5 | 42.3 | 98.6 | 86.0 | 11.6 | 397 |
| Feb. 1 | 4.34 | 4.01 | 146 | 184 | .79 | 47.0 | 46.0 | 94.3 | 92.3 | 12.4 | 390 |
| *Can.* | | | | | | | | | | | |
| Sept. 27 | 6.42 | 5.83 | 201 | 266 | .75 | ........ | 35.8 | 179.3 | ........ | 13.0 | 542 |
| Oct. 4 | 6.03 | 5.42 | 212 | 253 | .84 | ........ | 38.9 | 155.0 | ........ | 11.3 | 588 |
| 10 | 5.60 | 5.10 | 180 | 251 | .72 | ........ | 39.2 | 142.8 | ........ | 13.0 | 474 |
| 25 | 5.59 | 4.96 | 183 | 240 | .76 | ........ | 40.1 | 139.4 | ........ | 12.5 | 487 |
| Nov. 7 | 5.38 | 4.98 | 180 | 232 | .78 | 45.4 | 37.5 | 143.5 | 118.5 | 11.1 | 542 |
| 14 | 5.31 | 4.83 | 165 | 226 | .73 | 45.5 | 37.4 | 142.0 | 116.7 | 12.0 | 487 |
| 20 | 5.48 | 4.96 | 175 | 222 | .79 | 44.1 | 37.3 | 146.9 | 124.3 | 11.6 | 519 |
| 27 | 5.76 | 5.30 | 189 | 228 | .83 | 46.6 | 37.8 | 152.4 | 123.6 | 12.0 | 526 |
| Dec. 7 | 5.16 | 4.72 | 171 | 225 | .76 | 45.6 | 39.2 | 131.6 | 113.2 | 11.5 | 497 |
| 14 | 5.93 | 5.24 | 188 | 227 | .83 | 46.1 | 37.1 | 159.8 | 128.6 | 12.4 | 527 |
| Jan. 7 | 6.18 | 5.47 | 204 | 251 | .81 | 45.9 | 37.9 | 163.1 | 134.6 | 12.0 | 558 |
| 11 | 5.87 | 5.33 | 185 | 245 | .76 | 44.1 | 35.6 | 164.9 | 133.1 | 11.9 | 548 |
| 15 | 5.46 | 4.87 | 180 | 221 | .81 | 46.3 | 38.5 | 141.8 | 117.9 | 11.5 | 524 |
| 19 | 5.40 | 4.84 | 169 | 226 | .75 | 44.6 | 39.5 | 136.7 | 121.1 | 13.1 | 453 |
| 22 | 5.31 | 4.80 | 172 | 219 | .79 | 45.5 | 38.1 | 139.4 | 116.7 | 11.4 | 511 |
| 26 | 5.64 | 5.13 | 178 | 225 | .79 | 45.1 | 35.9 | 157.1 | 125.1 | 11.5 | 543 |
| Feb. 2 | 5.48 | 5.03 | 184 | 230 | .80 | ........ | 38.7 | 141.6 | ........ | 11.6 | 522 |
| *Fre.* | | | | | | | | | | | |
| Oct. 2 | 5.86 | 5.36 | 166 | 215 | .77 | ........ | 43.3 | 135.3 | ........ | 18.7 | 346 |
| 5 | 6.28 | 5.72 | 176 | 224 | .78 | ........ | 42.8 | 146.7 | ........ | 20.0 | 349 |
| 11 | 6.20 | 5.62 | 177 | 227 | .78 | ........ | 44.1 | 140.6 | ........ | 19.7 | 345 |
| 18 | 5.84 | 5.33 | 164 | 217 | .76 | ........ | 45.5 | 128.3 | ........ | 19.5 | 327 |
| *Kon.* | | | | | | | | | | | |
| Oct. 27 | 6.43 | 5.80 | 212 | 265 | .79 | ........ | 42.9 | 149.9 | ........ | 16.2 | 433 |
| 29 | 5.64 | 5.13 | 204 | 257 | .79 | ........ | 42.7 | 132.1 | ........ | 12.2 | 507 |
| 30 | 6.61 | 5.84 | 211 | 267 | .79 | ........ | 36.4 | 181.6 | ........ | 12.8 | 564 |

[1]Computed following example of Loewy and Zuntz (Berl. klin. Wochenschr., 1916, 53, p. 828).
[2]Computed to 37° C., saturated, and prevailing barometric pressure.

TABLE 111.—*Ventilation of lungs and alveolar $CO_2$ tension in valve-apparatus experiments; subjects post-absorptive and in lying position—Squad A*—continued.

| Subject and date. | Per minute. (a) Ventilation of lungs (observed). | Per minute. (b) Ventilation of lungs (reduced). | Per minute. (c) Carbon dioxide. | Per minute. (d) Oxygen. | (e) Respiratory quotient. | (f) Alveolar $CO_2$ tension (determined). | (g) Alveolar $CO_2$ tension (calculated). | Ventilation (observed) per minute per mm. $CO_2$ tension.[1] (h) From calculated $CO_2$ tension (a÷g). | Ventilation (observed) per minute per mm. $CO_2$ tension.[1] (i) From determined $CO_2$ tension (a÷f). | (j) Respiration rate per minute. | (k) Volume per respiration.[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Kon*—cont. | *liters.* | *liters.* | *c.c.* | *c.c.* | | *mm.Hg.* | *mm.Hg.* | *c.c.* | *c.c.* | | *c.c.* |
| Nov. 2 | 5.93 | 5.44 | 187 | 251 | .75 | ........ | 40.0 | 148.2 | ........ | 14.9 | 440 |
| 4 | 6.31 | 5.85 | 193 | 246 | .78 | ........ | 40.6 | 155.4 | ........ | 17.2 | 406 |
| 6 | 5.40 | 4.89 | 176 | 240 | .73 | 44.5 | 40.0 | 135.0 | 121.3 | 12.5 | 474 |
| 8 | 5.43 | 4.91 | 177 | 240 | .74 | 47.8 | 39.8 | 136.4 | 113.6 | 12.4 | 478 |
| 15 | 5.91 | 5.33 | 184 | 245 | .76 | 46.0 | 40.9 | 144.5 | 128.5 | 15.3 | 424 |
| 21 | 5.00 | 4.47 | 160 | 214 | .75 | 44.7 | 40.3 | 124.1 | 111.9 | 12.0 | 458 |
| 28 | 5.35 | 4.87 | 165 | 210 | .79 | 48.1 | 39.8 | 134.4 | 111.2 | 13.6 | 432 |
| Dec. 5 | 5.38 | 4.85 | 183 | 225 | .81 | 48.9 | 43.6 | 123.4 | 110.0 | 13.4 | 441 |
| 15 | 6.04 | 5.52 | 184 | 232 | .79 | 47.5 | 39.4 | 153.3 | 127.2 | 15.7 | 426 |
| Jan. 12 | 5.81 | 5.06 | 189 | 242 | .78 | 49.8 | 43.2 | 134.5 | 116.7 | 14.7 | 435 |
| 15 | 5.92 | 5.28 | 184 | 239 | .77 | 47.9 | 41.9 | 141.3 | 123.6 | 15.9 | 413 |
| 18 | 5.96 | 5.40 | 174 | 235 | .74 | 45.7 | 38.9 | 153.2 | 130.4 | 15.9 | 414 |
| 22 | 5.46 | 4.95 | 166 | 207 | .80 | 49.9 | 41.6 | 131.3 | 109.4 | 15.1 | 398 |
| 26 | 4.96 | 4.50 | 157 | 201 | .78 | 48.1 | 41.3 | 120.1 | 103.1 | 12.9 | 426 |
| 31 | 5.50 | 5.06 | 166 | 203 | .82 | 46.9 | 41.0 | 134.1 | 117.3 | 15.4 | 395 |
| *Gar.* | | | | | | | | | | | |
| Sept. 27 | 5.85 | 5.28 | 213 | 271 | .79 | ........ | 40.9 | 143.0 | ........ | 11.1 | 575 |
| Oct. 4 | 5.71 | 5.13 | 196 | 244 | .80 | ........ | 42.5 | 134.3 | ........ | 13.4 | 469 |
| 10 | 5.43 | 4.94 | 181 | 239 | .76 | ........ | 40.9 | 132.8 | ........ | 12.7 | 470 |
| 17 | 5.09 | 4.66 | 177 | 234 | .76 | ........ | 41.2 | 123.5 | ........ | 11.2 | 499 |
| 23 | 5.05 | 4.63 | 165 | 221 | .75 | ........ | 40.4 | 125.0 | ........ | 12.1 | 459 |
| Nov. 1 | 5.02 | 4.52 | 164 | 220 | .75 | ........ | 41.9 | 119.8 | ........ | 12.3 | 444 |
| 7 | 5.22 | 4.83 | 169 | 219 | .78 | 44.3 | 39.5 | 132.2 | 117.8 | 12.7 | 461 |
| 14 | 4.88 | 4.44 | 157 | 211 | .75 | 44.1 | 41.1 | 118.7 | 110.7 | 12.2 | 439 |
| 20 | 4.55 | 4.11 | 154 | 209 | .74 | 43.4 | 42.1 | 108.1 | 104.8 | 10.8 | 462 |
| 28 | 4.86 | 4.42 | 156 | 211 | .74 | 43.5 | 39.9 | 121.8 | 111.7 | 11.6 | 459 |
| Dec. 7 | 4.69 | 4.28 | 151 | 205 | .74 | 44.3 | 40.2 | 116.7 | 105.9 | 11.5 | 452 |
| 14 | 4.99 | 4.39 | 170 | 202 | .84 | 43.8 | 40.6 | 122.9 | 113.9 | 10.7 | 514 |
| Jan. 10 | 6.00 | 5.44 | 177 | 237 | .75 | 44.0 | 32.0 | 187.5 | 136.4 | 11.3 | 596 |
| 14 | 5.83 | 5.38 | 195 | 223 | .87 | 45.0 | 39.6 | 147.2 | 129.6 | 13.5 | 485 |
| 18 | 5.46 | 4.95 | 173 | 230 | .75 | 42.6 | 38.8 | 140.7 | 128.2 | 12.8 | 471 |
| 22 | 4.66 | 4.23 | 148 | 194 | .76 | 43.2 | 39.5 | 118.0 | 107.9 | 11.2 | 458 |
| 25 | 5.11 | 4.59 | 155 | 203 | .76 | 42.4 | 38.6 | 132.4 | 120.5 | 12.7 | 445 |
| 31 | 4.86 | 4.47 | 153 | 200 | .77 | 44.3 | 41.4 | 117.4 | 109.7 | 13.0 | 414 |
| *Gul.* | | | | | | | | | | | |
| Oct. 1 | 5.90 | 5.36 | 210 | 249 | .84 | ........ | 37.8 | 156.1 | ........ | 10.4 | 634 |
| 7 | 5.72 | 5.28 | 192 | 241 | .80 | ........ | 36.8 | 155.4 | ........ | 11.0 | 577 |
| 13 | 5.84 | 5.24 | 181 | 235 | .77 | ........ | 38.7 | 150.9 | ........ | 13.8 | 463 |
| 20 | 5.31 | 4.85 | 170 | 228 | .75 | ........ | 34.0 | 156.2 | ........ | 9.3 | 634 |
| 22 | 5.11 | 4.58 | 168 | 221 | .76 | ........ | 38.4 | 133.2 | ........ | 10.5 | 530 |
| 31 | 5.38 | 4.99 | 178 | 220 | .81 | ........ | 35.7 | 150.7 | ........ | 10.2 | 592 |
| Nov. 4 | 5.71 | 5.29 | 181 | 224 | .81 | ........ | 38.6 | 147.9 | ........ | 13.6 | 464 |
| 10 | 5.33 | 4.84 | 171 | 207 | .81 | 41.6 | 35.7 | 149.3 | 128.1 | 10.4 | 570 |
| 17 | 5.26 | 4.75 | 164 | 213 | .77 | 44.6 | 39.6 | 132.8 | 117.9 | 12.9 | 448 |

[1]Computed following example of Loewy and Zuntz (Berl. klin. Wochenschr., 1916, 53, p. 828).
[2]Computed to 37° C., saturated, and prevailing barometric pressure.

TABLE 111.—*Ventilation of lungs and alveolar $CO_2$ tension in valve-apparatus experiments; subjects post absorptive and in lying position—Squad A*—continued.

| Subject and date. | Per minute. (*a*) Ventilation of lungs (observed). | Per minute. (*b*) Ventilation of lungs (reduced). | Per minute. (*c*) Carbon dioxide. | Per minute. (*d*) Oxygen. | (*e*) Respiratory quotient. | (*f*) Alveolar $CO_2$ tension (determined). | (*g*) Alveolar $CO_2$ tension (calculated). | Ventilation (observed) per minute per mm. $CO_2$ tension.[1] (*h*) From calculated $CO_2$ tension $(a \div g)$. | Ventilation (observed) per minute per mm. $CO_2$ tension.[1] (*i*) From determined $CO_2$ tension $(a \div f)$. | (*j*) Respiration rate per minute. | (*k*) Volume per respiration.[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Gul*—cont. | *liters.* | *liters.* | *c.c.* | *c.c.* | | *mm.Hg.* | *mm.Hg.* | *c.c.* | *c.c.* | | *c.c.* |
| Nov. 23 | 5.19 | 4.59 | 157 | 198 | .79 | 44.7 | 39.2 | 132.4 | 116.1 | 12.8 | 443 |
| 27 | 5.56 | 5.10 | 172 | 208 | .83 | 45.5 | 39.6 | 140.4 | 122.2 | 13.9 | 437 |
| Dec. 4 | 4.97 | 4.50 | 159 | 214 | .74 | 45.9 | 43.0 | 115.6 | 108.3 | 13.4 | 410 |
| 11 | 5.44 | 5.01 | 179 | 197 | .91 | 47.5 | 38.5 | 141.3 | 114.5 | 11.9 | 505 |
| 17 | 4.82 | 4.45 | 160 | 193 | .83 | 46.8 | 41.0 | 117.6 | 103.0 | 11.4 | 461 |
| Jan. 9 | 5.20 | 4.68 | 170 | 215 | .79 | 46.6 | 42.7 | 121.8 | 111.6 | 13.6 | 426 |
| 14 | 6.00 | 5.53 | 209 | 240 | .87 | 48.5 | 41.8 | 143.5 | 123.7 | 14.2 | 474 |
| 18 | 5.33 | 4.83 | 161 | 223 | .72 | 44.8 | 39.7 | 134.3 | 119.0 | 14.0 | 421 |
| 21 | 4.53 | 4.23 | 143 | 184 | .78 | 43.1 | 41.9 | 108.1 | 105.1 | 12.8 | 399 |
| 25 | 5.19 | 4.66 | 153 | 192 | .80 | 45.1 | 38.5 | 134.8 | 115.1 | 13.4 | 429 |
| 31 | 5.17 | 4.75 | 156 | 200 | .78 | 43.4 | 40.6 | 127.3 | 119.1 | 14.3 | 400 |
| *Mon.* | | | | | | | | | | | |
| Sept. 29 | 6.47 | 5.85 | 203 | 273 | .74 | ........ | 39.1 | 165.5 | ........ | 15.5 | 460 |
| Oct. 6 | 6.86 | 6.20 | 207 | 264 | .78 | ........ | 35.4 | 193.8 | ........ | 14.7 | 514 |
| 12 | 6.37 | 5.80 | 198 | 260 | .76 | ........ | 37.4 | 170.3 | ........ | 14.6 | 482 |
| 19 | 6.45 | 5.82 | 194 | 258 | .75 | ........ | 38.5 | 167.5 | ........ | 15.9 | 443 |
| 21 | 5.93 | 5.46 | 193 | 241 | .80 | ........ | 37.6 | 157.7 | ........ | 12.7 | 517 |
| Nov. 3 | 5.19 | 4.74 | 154 | 226 | .68 | ........ | 36.7 | 141.4 | ........ | 12.4 | 461 |
| 9 | 4.95 | 4.47 | 162 | 218 | .75 | 43.7 | 41.5 | 119.3 | 113.3 | 12.1 | 448 |
| 16 | 6.18 | 5.54 | 185 | 236 | .79 | 44.6 | 37.2 | 166.1 | 138.6 | 14.5 | 468 |
| 22 | 6.32 | 5.62 | 185 | 231 | .80 | 43.2 | 36.0 | 175.6 | 146.3 | 14.5 | 479 |
| Dec. 3 | 6.17 | 5.61 | 204 | 222 | .92 | 45.5 | 37.5 | 164.5 | 135.6 | 12.6 | 544 |
| 10 | 6.73 | 6.12 | 216 | 244 | .89 | 44.4 | 36.5 | 184.4 | 151.6 | 13.9 | 539 |
| 16 | 5.86 | 5.46 | 187 | 210 | .89 | 50.1 | 37.8 | 155.0 | 117.0 | 13.2 | 489 |
| Jan. 10 | 5.81 | 5.27 | 169 | 225 | .75 | 43.7 | 32.9 | 176.6 | 133.0 | 12.1 | 540 |
| 14 | 5.89 | 5.43 | 191 | 217 | .88 | 43.3 | 36.1 | 163.2 | 136.0 | 12.0 | 551 |
| 17 | 5.19 | 4.71 | 164 | 217 | .76 | 47.8 | 37.9 | 136.9 | 108.6 | 11.8 | 487 |
| 21 | 6.52 | 6.06 | 195 | 231 | .84 | 49.0 | 34.9 | 186.8 | 133.1 | 14.8 | 495 |
| 25 | 5.13 | 4.62 | 159 | 212 | .75 | 46.9 | 38.0 | 135.0 | 109.4 | 12.1 | 471 |
| 30 | 6.07 | 5.63 | 182 | 225 | .81 | 45.4 | 36.2 | 167.7 | 133.7 | 14.4 | 469 |
| *Moy.* | | | | | | | | | | | |
| Oct. 1 | 4.84 | 4.39 | 178 | 209 | .85 | ........ | 46.5 | 104.1 | ........ | 12.2 | 443 |
| 7 | 5.35 | 4.95 | 177 | 232 | .76 | ........ | 41.1 | 130.2 | ........ | 13.3 | 447 |
| 13 | 5.14 | 4.61 | 170 | 224 | .76 | ........ | 42.2 | 121.8 | ........ | 12.5 | 450 |
| 20 | 5.01 | 4.57 | 172 | 224 | .77 | ........ | 41.1 | 121.9 | ........ | 11.4 | 488 |
| Nov. 10 | 5.08 | 4.62 | 161 | 209 | .77 | 44.8 | 40.1 | 126.7 | 113.4 | 12.8 | 443 |
| 17 | 4.78 | 4.31 | 149 | 202 | .74 | 45.7 | 40.2 | 118.7 | 104.6 | 12.0 | 438 |
| 23 | 4.52 | 3.99 | 146 | 194 | .75 | 46.2 | 43.5 | 103.9 | 97.8 | 11.8 | 419 |
| Dec. 4 | 4.55 | 4.12 | 154 | 202 | .76 | 46.4 | 42.3 | 107.6 | 98.1 | 11.0 | 456 |
| 11 | 4.54 | 4.16 | 157 | 188 | .83 | 47.6 | 43.2 | 105.1 | 95.4 | 11.1 | 450 |
| 17 | 4.75 | 4.37 | 158 | 196 | .81 | 48.3 | 42.3 | 112.3 | 98.3 | 11.7 | 441 |
| Jan. 9 | 5.32 | 4.79 | 177 | 229 | .77 | 46.4 | 39.7 | 134.0 | 114.7 | 12.0 | 493 |
| 17 | 4.94 | 4.49 | 162 | 218 | .74 | 47.2 | 39.9 | 123.8 | 104.7 | 11.6 | 472 |
| 20 | 4.58 | 4.21 | 153 | 194 | .79 | 47.1 | 41.1 | 111.4 | 97.2 | 11.2 | 456 |
| 24 | 4.84 | 4.35 | 154 | 198 | .78 | 46.2 | 40.2 | 120.4 | 104.8 | 11.8 | 451 |
| 30 | 4.60 | 4.26 | 154 | 191 | .81 | 47.3 | 39.9 | 115.3 | 97.3 | 10.6 | 482 |

[1]Computed following example of Loewy and Zuntz (Berl. klin. Wochenschr., 1916, 53, p. 828).
[2]Computed to 37° C., saturated, and prevailing barometric pressure.

TABLE 111.—*Ventilation of lungs and alveolar $CO_2$ tension in valve-apparatus experiments; subjects post absorptive and in lying position—Squad A*—continued.

| Subject and date. | Per minute. (a) Ventilation of lungs (observed). | (b) Ventilation of lungs (reduced). | (c) Carbon dioxide. | (d) Oxygen. | (e) Respiratory quotient. | (f) Alveolar $CO_2$ tension (determined). | (g) Alveolar $CO_2$ tension (calculated). | Ventilation (observed) per minute per mm. $CO_2$ tension.[1] (h) From calculated $CO_2$ tension (a+g). | (i) From determined $CO_2$ tension (a+f). | (j) Respiration rate per minute. | (k) Volume per respiration.[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Spe*—cont. | *liters.* | *liters.* | *c.c.* | *c.c.* | | *mm.Hg.* | *mm.Hg.* | *c.c.* | *c.c.* | | *c.c.* |
| Nov. 1 | 4.99 | 4.49 | 163 | 208 | .78 | ........ | 39.9 | 125.1 | ........ | 11.2 | 484 |
| 5 | 5.21 | 4.81 | 166 | 208 | .80 | 35.1 | 39.2 | 132.9 | 148.4 | 12.5 | 459 |
| 12 | 5.10 | 4.55 | 173 | 198 | .87 | 44.8 | 39.6 | 128.8 | 113.8 | 10.4 | 534 |
| 18 | 4.84 | 4.36 | 150 | 193 | .78 | 41.2 | 37.5 | 129.1 | 117.5 | 10.9 | 487 |
| 24 | 4.54 | 4.06 | 146 | 186 | .78 | 40.4 | 39.6 | 114.6 | 112.4 | 10.6 | 473 |
| Dec. 8 | 4.21 | 3.86 | 142 | 187 | .76 | 43.4 | 40.9 | 102.9 | 97.0 | 9.8 | 474 |
| *Tom.* | | | | | | | | | | | |
| Oct. 3 | 5.19 | 4.74 | 170 | 204 | .83 | ........ | 43.9 | 118.2 | ........ | 14.1 | 405 |
| 9 | 5.34 | 4.91 | 172 | 224 | .77 | ........ | 39.9 | 133.8 | ........ | 13.1 | 453 |
| 16 | 5.45 | 4.88 | 159 | 204 | .78 | ........ | 38.9 | 140.1 | ........ | 14.2 | 419 |
| 22 | 5.28 | 4.73 | 162 | 205 | .79 | ........ | 41.2 | 128.2 | ........ | 13.8 | 416 |
| 31 | 4.79 | 4.44 | 146 | 191 | .76 | ........ | 39.2 | 122.2 | ........ | 12.8 | 420 |
| Nov. 13 | 4.28 | 3.94 | 141 | 173 | .82 | 50.5 | 42.9 | 99.8 | 84.8 | 11.3 | 419 |
| 19 | 4.25 | 3.91 | 136 | 177 | .77 | 46.7 | 42.9 | 99.1 | 91.0 | 11.8 | 402 |
| 26 | 5.17 | 4.75 | 176 | 182 | .97 | 47.9 | 40.3 | 128.3 | 107.9 | 11.6 | 493 |
| Dec. 6 | 4.26 | 3.89 | 136 | 181 | .76 | 48.7 | 43.6 | 97.7 | 87.5 | 11.9 | 397 |
| 13 | 4.61 | 4.18 | 143 | 187 | .76 | 49.3 | 42.4 | 108.7 | 93.5 | 12.5 | 400 |
| 19 | 4.41 | 4.05 | 128 | 169 | .76 | 46.5 | 41.5 | 106.3 | 94.8 | 13.0 | 372 |
| Jan. 12 | 5.02 | 4.39 | 159 | 198 | .80 | 50.6 | 42.7 | 117.6 | 99.2 | 13.1 | 420 |
| 16 | 4.68 | 4.28 | 143 | 194 | .74 | 47.6 | 41.3 | 113.3 | 98.3 | 13.2 | 398 |
| 20 | 4.32 | 3.96 | 135 | 180 | .75 | 49.9 | 43.2 | 100.0 | 86.6 | 12.4 | 388 |
| 23 | 4.67 | 4.17 | 137 | 172 | .80 | 47.1 | 41.5 | 112.5 | 99.2 | 13.3 | 387 |
| 29 | 4.23 | 3.79 | 135 | 170 | .79 | 48.9 | 45.7 | 92.6 | 86.5 | 12.1 | 381 |
| *Vea.* | | | | | | | | | | | |
| Oct. 2 | 5.29 | 4.85 | 178 | 227 | .78 | ........ | 40.4 | 130.9 | ........ | 12.2 | 480 |
| 8 | 4.76 | 4.35 | 161 | 219 | .74 | ........ | 40.1 | 118.7 | ........ | 10.6 | 496 |
| 15 | 5.48 | 4.90 | 168 | 217 | .78 | ........ | 40.1 | 136.7 | ........ | 13.8 | 432 |
| 21 | 4.39 | 4.04 | 151 | 210 | .72 | ........ | 44.8 | 98.0 | ........ | 11.6 | 419 |
| 27 | 4.93 | 4.45 | 152 | 206 | .74 | ........ | 42.1 | 117.1 | ........ | 13.4 | 402 |
| Nov. 5 | 5.02 | 4.63 | 157 | 215 | .73 | 31.9 | 43.7 | 114.9 | 157.4 | 14.5 | 381 |
| 12 | 5.44 | 4.86 | 179 | 214 | .84 | 45.9 | 42.8 | 127.1 | 118.5 | 13.6 | 436 |
| 18 | 4.31 | 3.88 | 146 | 191 | .77 | 47.7 | 43.6 | 98.9 | 90.4 | 10.8 | 438 |
| 24 | 4.37 | 3.90 | 142 | 179 | .79 | 44.9 | 41.4 | 105.6 | 97.3 | 10.7 | 450 |
| Dec. 5 | 4.63 | 4.17 | 151 | 191 | .79 | 47.8 | 43.1 | 107.4 | 96.9 | 12.1 | 420 |
| 12 | 4.22 | 3.88 | 149 | 186 | .80 | 49.4 | 47.4 | 89.0 | 85.4 | 11.4 | 405 |
| 18 | 4.48 | 4.18 | 145 | 186 | .78 | 48.7 | 42.8 | 104.7 | 92.0 | 12.2 | 406 |
| Jan. 8 | 4.82 | 4.30 | 158 | 200 | .79 | 48.5 | 44.2 | 109.0 | 99.4 | 13.0 | 412 |
| 11 | 5.24 | 4.76 | 162 | 200 | .81 | 44.7 | 39.0 | 134.4 | 117.2 | 13.1 | 445 |
| 16 | 4.88 | 4.45 | 149 | 190 | .78 | 46.4 | 39.2 | 124.5 | 105.2 | 12.7 | 431 |
| 19 | 4.49 | 4.04 | 147 | 188 | .78 | 45.9 | 40.4 | 111.1 | 97.8 | 10.6 | 467 |
| 23 | 4.63 | 4.13 | 144 | 188 | .77 | 45.4 | 41.2 | 112.4 | 102.0 | 12.1 | 421 |
| 29 | 4.43 | 3.97 | 151 | 180 | .84 | 47.2 | 41.7 | 106.2 | 93.9 | 10.0 | 483 |
| Feb. 1 | 4.49 | 4.13 | 145 | 178 | .81 | 46.8 | 42.9 | 104.7 | 95.9 | 12.2 | 408 |

[1]Computed following example of Loewy and Zuntz (Berl. klin. Wochenschr., 1916, 53, p. 828).
[2]Computed to 37° C., saturated, and prevailing barometric pressure.

TABLE 113.—*Normal basal metabolism of Squad A, prior to reduction in diet.*

| Subject. | Body-weight without clothing. | Height. | Body-surface by height-weight chart. | (a) Average $O_2$ per minute. | (b) Respiratory quotient. | Heat (computed). (c) Per hour. | Heat (computed). (d) Per 24 hours. | Heat (computed). (e) Per kg. per 24 hours. | Heat (computed). (f) Per sq. m. (height-weight chart) per 24 hours. | (g) Heat per 24 hours predicted by Harris and Benedict. | Difference found greater (+) or less (−) than Harris and Benedict predictions. (h) Amount (g−d). | Difference found greater (+) or less (−) than Harris and Benedict predictions. (i) Per cent (100h÷g). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | kg. | cm. | sq. m. | c.c. | | cals. | cals. | cals. | cals. | cals. | cals. | |
| Bro | 61.8 | 167 | 1.70 | 212 | 0.70[1] | 61.7 | 1481 | 24.0 | 871 | 1576 | − 95 | − 6.0 |
| Can | 79.8 | 177 | 1.97 | 255 | .80 | 73.3 | 1758 | 22.0 | 893 | 1874 | −116 | − 6.2 |
| Fre | 57.5 | 167 | 1.64 | 231 | .77 | 66.2 | 1589 | 27.6 | 969 | 1524 | + 65 | + 4.3 |
| Kon | 69.0 | 168 | 1.78 | 264 | .79 | 75.8 | 1818 | 26.4 | 1021 | 1721 | + 97 | + 5.6 |
| Gar | 71.3 | 171 | 1.83 | 263 | .80 | 75.6 | 1815 | 25.5 | 992 | 1754 | + 61 | + 3.5 |
| Gul | 66.8 | 166 | 1.75 | 244 | .84 | 70.8 | 1698 | 25.4 | 974 | 1653 | + 45 | + 2.7 |
| Mon | 68.8 | 171 | 1.81 | 273 | .74 | 77.4 | 1858 | 27.0 | 1027 | 1652 | +206 | +12.5 |
| Moy | 63.5 | 174 | 1.77 | 235 | .85 | 68.3 | 1638 | 25.8 | 926 | 1655 | − 17 | − 1.0 |
| Pea | 69.3 | 169 | 1.79 | 255 | .81 | 73.6 | 1766 | 25.5 | 987 | 1723 | + 43 | + 2.5 |
| Pec | 64.3 | 170 | 1.75 | 230 | .79 | 66.2 | 1589 | 24.7 | 908 | 1504 | + 85 | + 5.7 |
| Spe | 63.5 | 171 | 1.75 | 252 | .79 | 72.2 | 1733 | 27.3 | 990 | 1667 | + 66 | + 4.0 |
| Tom | 59.5 | 176 | 1.73 | 219 | .83 | 63.6 | 1526 | 25.6 | 882 | 1596 | − 70 | − 4.4 |
| Vea | 65.8 | 175 | 1.80 | 234 | .78 | 66.8 | 1604 | 24.4 | 891 | 1698 | − 94 | − 5.5 |
| Ham (Squad B) | 73.8 | 184 | 1.96 | 270 | .82 | 78.2 | 1877 | 25.4 | 958 | 1867 | + 10 | + 0.5 |

[1] In computing the heat values for this subject, the respiratory quotient for October 5 (0.84) was used.

tion per kilogram of body-weight was essentially the same at the beginning and end of the experiment, but the tables for the other subjects show that there is, with many, a distinct decrease in the heat production per kilogram of body-weight. High values are occasionally found, but, as will be subsequently shown, these are for the most part attributable to excess eating on either the uncontrolled days or during the holidays.

TABLE 115—*Basal metabolism of George A. Brown—Squad A.*

[1] The experiments reported in this table and in tables 116 to 127 were made with the portable respiration apparatus and the respiratory-valve apparatus. The subject was in all cases in the lying position and had been without food for at least 12 hours. Respiratory quotients were obtained with the respiratory-valve apparatus and have been used in computing the heat on the days when they were determined. On the remaining days (with the portable respiration apparatus) quotients were interpolated for the heat computations. No respiratory quotient below 0.73 has been used in the calculations.

TABLE 116.—*Basal metabolism of Kenneth B. Canfield—Squad A.*

TABLE 117.—*Basal metabolism of Lester F. Fretter—Squad A.*

TABLE 118.—*Basal metabolism of Everett R. Kontner—Squad A.*

TABLE 119.—*Basal metabolism of Greyson C. Gardner—Squad A.*

TABLE 119.—*Basal metabolism of Greyson C. Gardner—Squad A*—continued.

TABLE 120.—*Basal metabolism of Otto A. Gullickson—Squad A.*

TABLE 120.—*Basal metabolism of Otto A. Gullickson—Squad A*—continued.

TABLE 121.—*Basal metabolism of Kirk G. Montague—Squad A.*

TABLE 121.—*Basal metabolism of Kirk G. Montague—Squad A*—continued.

TABLE 122.—*Basal metabolism of Henry A. Moyer—Squad A.*

TABLE 122.—*Basal metabolism of Henry A. Moyer—Squad A*—continued.

TABLE 123.—*Basal metabolism of Allen S. Peabody—Squad A.*

TABLE 123.—*Basal metabolism of Allen S. Peabody—Squad A*—continued.

TABLE 124.—*Basal metabolism of R. Wallace Peckham—Squad A.*

TABLE 124.—*Basal metabolism of R. Wallace Peckham—Squad A*—continued.

TABLE 125.—*Basal metabolism of Wesley G. Spencer—Squad A.*

[1]On Oct. 27 *Spe* believed he had a touch of grippe. His oral temperature was 98.8° F. and average pulse-rate, 68.

TABLE 126.—*Basal metabolism of Leslie J. Tompkins—Squad A.*

| Date. | Oxygen per minute. | Respiratory quotient. | Heat (computed) per 24 hours. Total. | Per kg. of body-weight. | Per sq. meter of body-surface (height-weight chart). |
|---|---|---|---|---|---|
| *Normal.* | *c.c.* | | *cals.* | *cals.* | *cals.* |
| 1917. | | | | | |
| Sept. 27 | 219 | ...... | 1,526 | 25.6 | 882 |
| 28 | 246 | ...... | 1,714 | 28.8 | 991 |
| Oct. 1 | 204 | ...... | 1,421 | 23.9 | 821 |
| 2 | 222 | ...... | 1,546 | 26.0 | 894 |
| 3 | 204 | 0.83 | 1,421 | 23.9 | 821 |
| *Reduced.* | | | | | |
| Oct. 5 | 215 | ...... | 1,486 | 25.0 | 859 |
| 6 | 223 | ...... | 1,541 | 25.9 | 891 |
| 7 | 223 | ...... | 1,541 | 26.0 | 891 |
| 9 | 224 | 0.77 | 1,536 | 25.9 | 888 |
| 10 | 211 | ...... | 1,452 | 24.4 | 839 |
| 11 | 224 | ...... | 1,541 | 25.9 | 891 |
| 13 | 216 | ...... | 1,486 | 25.0 | 859 |
| 15 | 239 | ...... | 1,644 | 27.7 | 950 |
| 16 | 204 | 0.78 | 1,404 | 23.7 | 812 |
| 18 | 217 | ...... | 1,498 | 25.3 | 866 |
| 20 | 210 | ...... | 1,447 | 24.4 | 836 |
| 22 | 207 | 0.79 | 1,428 | 24.3 | 830 |
| 24 | 202 | ...... | 1,390 | 23.6 | 808 |
| 26 | 216 | ...... | 1,486 | 25.3 | 864 |
| 27 | 220 | ...... | 1,512 | 25.7 | 879 |
| 29 | 221 | ...... | 1,519 | 26.1 | 883 |
| 31 | 191 | 0.76 | 1,308 | 22.4 | 760 |
| Nov. 1 | 204 | ...... | 1,406 | 24.3 | 822 |
| 2 | 211 | ...... | 1,454 | 25.2 | 850 |
| 4 | 217 | ...... | 1,498 | 26.2 | 881 |
| 5 | 202 | ...... | 1,392 | 24.3 | 819 |
| 6 | 196 | ...... | 1,351 | 23.6 | 795 |
| 8 | 206 | ...... | 1,421 | 24.9 | 836 |
| 9 | 197 | ...... | 1,358 | 23.8 | 799 |
| 10 | 204 | ...... | 1,406 | 24.7 | 827 |
| 13 | 173 | 0.82 | 1,202 | 21.3 | 711 |
| 14 | 189 | ...... | 1,306 | 23.2 | 773 |
| *Reduced.* | *c.c.* | | *cals.* | *cals.* | *cals.* |
| 1917. | | | | | |
| Nov. 15 | 192 | ...... | 1,327 | 23.4 | 781 |
| 17 | 197 | ...... | 1,361 | 24.0 | 801 |
| 18 | 191 | ...... | 1,320 | 23.7 | 786 |
| 19 | 177 | 0.77 | 1,214 | 21.8 | 723 |
| 21 | 185 | ...... | 1,301 | 23.2 | 770 |
| 22 | 188 | ...... | 1,322 | 23.6 | 782 |
| 24 | 185 | ...... | 1,301 | 23.3 | 774 |
| 26 | 182 | 0.97 | 1,313 | 23.5 | 782 |
| 27 | 174 | ...... | 1,224 | 21.7 | 724 |
| Dec. 4 | 201 | ...... | 1,414 | 25.3 | 837 |
| 5 | 201 | ...... | 1,414 | 25.3 | 837 |
| 6 | 181 | 0.76 | 1,238 | 22.1 | 733 |
| 8 | 186 | ...... | 1,272 | 22.8 | 757 |
| 10 | 197 | ...... | 1,349 | 24.4 | 803 |
| 11 | 193 | ...... | 1,320 | 23.6 | 781 |
| 13 | 187 | 0.76 | 1,279 | 22.9 | 761 |
| 14 | 200 | ...... | 1,368 | 24.5 | 814 |
| 15 | 192 | ...... | 1,313 | 23.7 | 782 |
| 17 | 192 | ...... | 1,313 | 23.7 | 782 |
| 19 | 169 | 0.76 | 1,157 | 20.9 | 689 |
| 1918. | | | | | |
| Jan. 12 | 198 | 0.80 | 1,368 | 24.3 | 809 |
| 14 | 194 | ...... | 1,332 | 23.4 | 784 |
| 16 | 194 | 0.74 | 1,320 | 23.8 | 786 |
| 18 | 209 | ...... | 1,426 | 25.8 | 849 |
| 20 | 180 | 0.75 | 1,229 | 22.3 | 736 |
| 21 | 195 | ...... | 1,342 | 24.3 | 799 |
| 22 | 197 | ...... | 1,356 | 24.4 | 807 |
| 23 | 172 | 0.80 | 1,188 | 21.4 | 707 |
| 25 | 187 | ...... | 1,294 | 23.5 | 775 |
| 28 | 171 | ...... | 1,183 | 21.5 | 708 |
| 29 | 170 | 0.79 | 1,171 | 21.5 | 701 |
| Feb. 1 | 188 | ...... | 1,296 | 23.6 | 776 |

TABLE 127.—*Basal metabolism of Ronald T. Veal—Squad A.*

### TOTAL HEAT OUTPUT WITH LOW DIET, SQUAD A.

For a consideration of the total heat production of the squad at the beginning of the experiment, we have collected the data for all of the men in Squad A, except *Spe*, prior to diet restriction, and likewise the total heat output on the last three days of the experiment, and compared them in table 128. The values at the beginning of the experiment are usually the average of 3 to 5 days, but in the case of *Mon* 1 day is used. The total basal heat production at the beginning ranged from a minimum of 1,481 calories with *Bro* to a maximum of 1,858 calories with *Mon*. The average for the 11 men was 1,686 calories. The three measurements with *Kon* used for his normal average were

The normal heat production, which was found on September 29–30 and has previously been recorded in table 114, is 1.10 calories per kilogram per hour and 40.8 calories per square meter per hour. The restricted diet began with breakfast on the morning of October 4. Approximately 10 days later (October 13–14), a second metabolism experiment showed a profound fall in the heat production to 1.02 calories per kilogram per hour and 37.6 calories per square meter per hour, a decrease of 7.3 per cent and 7.8 per cent, respectively. It so happens that these first two experiments represented values obtained with exactly the same personnel.

TABLE 131.—*Minimum metabolism during sleep as measured in group respiration chamber—Squad A.*

| Date. | Total body-weight without clothing. | Total body-surface (height-weight chart). | Total carbon dioxide per hour. | Heat (computed) per hour. | |
|---|---|---|---|---|---|
| | | | | Per kilogram. | Per sq. meter. |
| Normal diet: | *kg.* | *sq. meters.* | *gm.* | *cals.* | *cals.* |
| Sept. 29–30, 1917. | 792 | 21.3 | 287 | 1.10 | 40.8 |
| Reduced diet: | | | | | |
| Oct. 13–14, 1917. | 777 | 21.1 | 249 | 1.02 | 37.6 |
| Oct. 27–28, 1917. | [1]695 | 19.2 | 222 | 1.01 | 36.4 |
| Nov. 10–11, 1917. | 733 | 20.6 | 225 | 0.97 | 34.4 |
| Nov. 24–25, 1917. | 724 | 20.5 | 215 | 0.94 | 33.0 |
| Dec. 8–9, 1917. | 711 | 20.3 | 224 | 0.98 | 34.4 |
| Dec. 19–20, 1917. | [1]654 | 18.7 | 208 | 0.96 | 33.7 |
| Jan. 12–13, 1918. | [1]680 | 19.0 | 204 | 0.95 | 33.8 |
| Jan. 26–27, 1918. | [1]665 | 18.8 | 192 | 0.90 | 31.8 |
| Feb. 2–3, 1918. | [1]662 | 18.8 | 193 | 0.89 | 31.4 |

[1] Values represent 11 men only.

In the experiment on the night of October 27–28 but 11 men were in the squad. Hence there was a change in the total body-weight and body-surface and in the carbon-dioxide production. The heat production per kilogram of body-weight, however, is nearly identical with that obtained two weeks before, namely, 1.01 calories, but there was a decrease in the heat per square meter from 37.6 to 36.4 calories.

On November 10–11 the squad again consisted of 12 men and the heat production changed to 0.97 calorie per kilogram and 34.4 calories per square meter. These values remained essentially constant for the next four experiments, these being made on the nights of November 24–25, December 8–9, December 19–20, and January 12–13. It should be noted that beginning with December 19–20, the values are again for 11 men. On the night of January 26–27 another decided alteration was found in the heat production per kilogram of body-weight, which fell to 0.90 calorie, and in the heat production per square meter of body-surface, which fell to 31.8 calories. One week later, February 2–3, the

TABLE 133.—*Heat production at different diet levels as computed from respiration experiments and as predicted by Harris and Benedict—Squad A; subjects post-absorptive and in lying position.*

| Subject. | (a) Age. | (b) Height. | (c) Body-weight without clothing. | Heat per 24 hours. (d) Predicted by Harris and Benedict. | (e) Computed from respiration experiments.[2] | Computed heat greater (+) or less (−) than predicted. (f) Total. $(d-e)$ | (g) Per cent. $\left(\frac{f\times100}{d}\right)$ |
|---|---|---|---|---|---|---|---|
| During normal diet.[1] | | | | | | | |
| | *yrs.* | *cm.* | *kg.* | *cals.* | *cals.* | *cals.* | |
| Bro.... | 26 | 167 | 61.8 | 1,576 | 1,481 | − 95 | − 6.0 |
| Can.... | 26 | 177 | 79.8 | 1,874 | 1,758 | −116 | − 6.2 |
| Kon[3]... | 20 | 168 | 69.0 | 1,721 | 1,818 | + 97 | + 5.6 |
| Gar.... | 22 | 171 | 71.3 | 1,754 | 1,815 | + 61 | + 3.5 |
| Gul.... | 24 | 166 | 66.8 | 1,653 | 1,698 | + 45 | + 2.7 |
| Mon... | 32 | 171 | 68.8 | 1,652 | 1,858 | +206 | +12.5 |
| Moy... | 23 | 174 | 63.5 | 1,655 | 1,638 | − 17 | − 1.0 |
| Pea.... | 21 | 169 | 69.3 | 1,723 | 1,766 | + 43 | + 2.5 |
| Pec.... | 44 | 170 | 64.3 | 1,504 | 1,589 | + 85 | + 5.7 |
| Spe.... | 19 | 171 | 63.5 | 1,667 | 1,733 | + 66 | + 4.0 |
| Tom... | 25 | 176 | 59.5 | 1,596 | 1,526 | − 70 | − 4.4 |
| Vea.... | 22 | 175 | 65.8 | 1,698 | 1,604 | − 94 | − 5.5 |
| Av .. | 25 | 171 | 67.0 | 1,673 | 1,690 | + 18 | + 1.1 |

| Subject. | (h) Age. | (i) Height. | (j) Body-weight without clothing. | Heat per 24 hours. (k) Predicted by Harris and Benedict. | (l) Computed from respiration experiments.[2] | Computed heat greater (+) or less (−) than predicted. (m) Total. $(k-l)$ | (n) Per cent. $\left(\frac{m\times100}{k}\right)$ |
|---|---|---|---|---|---|---|---|
| At period of minimum weight.[4] | | | | | | | |
| | *yrs.* | *cm.* | *kg.* | *cals.* | *cals.* | *cals.* | |
| Bro.... | 26 | 166 | 55.8 | 1,489 | 1,307 | −182 | −12.2 |
| Can.... | 26 | 177 | 70.4 | 1,745 | 1,576 | −169 | − 9.7 |
| Kon.... | 20 | 168 | 64.6 | 1,660 | 1,453 | −207 | −12.5 |
| Gar.... | 22 | 172 | 63.8 | 1,656 | 1,477 | −179 | −10.8 |
| Gul.... | 24 | 165 | 60.5 | 1,561 | 1,467 | − 94 | − 6.0 |
| Mon... | 32 | 171 | 61.4 | 1,550 | 1,574 | + 24 | + 1.5 |
| Moy... | 23 | 175 | 57.6 | 1,579 | 1,370 | −209 | −13.2 |
| Pea.... | 21 | 169 | 62.1 | 1,624 | 1,362 | −262 | −16.1 |
| Pec.... | 44 | 171 | 59.8 | 1,447 | 1,314 | −133 | − 9.2 |
| Spe.... | 19 | 172 | 56.8 | 1,580 | 1,314 | −266 | −16.8 |
| Tom... | 25 | 176 | 56.0 | 1,549 | 1,292 | −257 | −16.6 |
| Vea.... | 22 | 174 | 60.3 | 1,618 | 1,324 | −294 | −18.2 |
| Av... | 25 | 171 | 60.8 | 1,588 | 1,403 | −186 | −11.7 |

[1] The normal diet period includes experiments during Sept. 27 to Oct. 4, 1917, inclusive.
[2] See tables 115 to 127.
[3] The normal values for *Kon* were obtained on Oct. 27, 29, and 30.
[4] The period of minimum weight-level represents 5 experiments on or about Nov. 24.

TABLE 133.—*Heat production at different diet levels as computed from respiration experiments and as predicted by Harris and Benedict—Squad A; subjects post-absorptive and in lying position*—continued.

| | At end of period with reduced diet.[1] | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | Heat per 24 hours. | | Computed heat greater (+) or less (−) than predicted. | |
| Subject. | (*o*) Age. | (*p*) Height. | (*q*) Body-weight without clothing. | (*r*) Predicted by Harris and Benedict. | (*s*) Computed from respiration experiments.[2] | (*t*) Total. $(r-s)$ | (*u*) Per cent. $\left(\frac{t \times 100}{r}\right)$ |
| | *yrs.* | *cm.* | *kg.* | *cals.* | *cals.* | *cals.* | |
| Bro.... | 26 | 167 | 54.9 | 1,481 | 1,188 | −293 | −19.8 |
| Can.... | 26 | 178 | 70.6 | 1,752 | 1,561 | −191 | −10.9 |
| Kon ... | 20 | 168 | 62.5 | 1,631 | 1,450 | −181 | −11.1 |
| Gar.... | 22 | 171 | 63.9 | 1,652 | 1,417 | −235 | −14.2 |
| Gul.... | 25 | 166 | 60.7 | 1,563 | 1,314 | −249 | −15.9 |
| Mon... | 32 | 171 | 60.7 | 1,540 | 1,538 | − 2 | − 0.1 |
| Moy... | 23 | 174 | 58.0 | 1,579 | 1,350 | −229 | −14.5 |
| Pea.... | 21 | 169 | 61.6 | 1,618 | 1,316 | −302 | −18.7 |
| Pec.... | 44 | 171 | 58.8 | 1,433 | 1,203 | −230 | −16.1 |
| Tom... | 26 | 176 | 55.1 | 1,529 | 1,238 | −291 | −19.0 |
| Vea.... | 22 | 174 | 58.6 | 1,594 | 1,269 | −325 | −20.4 |
| Av... | 26 | 171 | 60.5 | 1,579 | 1,349 | −230 | −14.6 |

[1] The period at the end of the reduced diet represents 5 experiments on or about Jan. 26, 1918.
[2] See tables 115 to 127.

derived from a series of prediction equations, it is obvious that the basis of comparison is much more fundamentally and firmly established than when the comparison is made on the basis of body-weight or body-surface.

It is seen, therefore, that not only on the basis of body-weight, as shown in earlier tables, as well as the questionable basis of body-surface, but also from these biometric prediction values, the basal metabolism was profoundly lowered with every member of Squad A. It is furthermore of significance that of the four men with pronounced negative values in column *g* on the normal diet, namely, *Bro*, *Can*, *Tom*, and *Vea*, three of them, *Bro*, *Tom*, and *Vea*, show absolutely greater negative values at the end of the experiment than all of the other subjects except *Pea*, thus suggesting a tendency to retain a relative position in the group so prominently indicated in the positive values noted with *Mon*.

## GROUP MEASUREMENT OF BASAL METABOLISM WITH LOW DIET, SQUAD B.

Immediately following the night of January 6 inside the respiration chamber, Squad B was put upon a much restricted diet which averaged 1,375 net calories. The men came to Boston for experiments in the group respiration chamber on January 13, 19, and 27,

TABLE 137.—*Comparison of energy metabolism in lying and standing positions—Squad A; subjects post-absorptive, at end of period of reduced diet.*

| Subject. | Lying (respiratory-valve or portable respiration apparatus). | | | | | | Standing (portable respiration apparatus). | | | Increase in heat, standing over lying. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date. | Body-weight without clothing. | Oxygen per minute. | Respiratory quotient. | Heat (computed). | | Body-weight without clothing (Feb. 3, 1918). | Heat (computed). | | Total increase. | P. ct. increase. |
| | | | | | Per hour. | Per kg. per hour. | | Per minute. | Per kg. per hour. | | |
| | 1918. | *kg.* | *c. c.* | | *cals.* | *cals.* | *kg.* | *cals.* | *cals.* | *cals.* | |
| Bro | Feb. 2 | 55.0 | 186 | [1]0.80 | 53.6 | 0.97 | 54.4 | 1.00 | 1.10 | 0.13 | 13.4 |
| Can | ...do | 70.5 | 230 | 0.80 | 66.3 | .94 | 69.3 | 1.27 | 1.10 | .16 | 17.0 |
| Kon | ...do | 62.5 | 213 | [1]0.80 | 61.4 | .98 | 61.5 | 1.03 | 1.00 | .02 | 2.0 |
| Gar | Feb. 1 | 65.0 | 223 | [1]0.80 | 64.2 | .99 | 63.0 | 1.22 | 1.16 | .17 | 17.2 |
| Gul | Jan. 31 | 60.5 | 200 | 0.78 | 57.3 | .95 | 61.0 | 1.01 | .99 | .04 | 4.2 |
| Mon | Feb. 1 | 60.8 | 219 | [1]0.80 | 63.1 | 1.04 | 60.6 | 1.16 | 1.15 | .11 | 10.6 |
| Moy | Feb. 2 | 59.0 | 197 | [1]0.80 | 56.7 | .96 | 57.8 | 1.11 | 1.15 | .19 | 19.8 |
| Pea | Feb. 1 | 61.0 | 185 | 0.79 | 53.2 | .87 | 61.3 | .97 | .95 | .08 | 9.2 |
| Pec | Feb. 2 | 59.0 | 185 | 0.79 | 53.2 | .90 | 59.1 | .97 | .99 | .09 | 10.0 |
| Tom | Feb. 1 | 54.8 | 188 | [1]0.80 | 54.2 | .99 | 55.1 | 1.00 | 1.09 | .10 | 10.1 |
| Vea | Feb. 2 | 58.8 | 189 | [1]0.80 | 54.4 | .93 | 58.5 | 1.01 | 1.04 | .11 | 11.8 |
| Average | ........ | ........ | ........ | ........ | ........ | .96 | ........ | ........ | 1.07 | .11 | 11.4 |

[1] Respiratory quotient of 0.80 assumed for the experiments with the portable respiration apparatus.

TABLE 138.—*Increase in the heat output during walking in treadmill chamber and the computed total heat required in walking 10 kilometers—Squad B normal, January 6, 1918.*

[1] Equivalent to 4.2 km. (2.6 miles) per hour, at rate of 70 meters per minute. [2] Average of quotients for five subjects. [3] Computed; see page 535. [4] Omitted in average. [5] Omitting McM.

TABLE 140.—*Increase in the heat output during walking in treadmill chamber and the computed total heat required in walking 10 km.—Squad B, 20 days restricted diet, January 28, 1918.*

| (a) Subject. | (b) Weight with clothes electrodes, etc. | (c) Distance per minute. | (d) Horizontal kg.meters per minute. (b×c). | (e) Carbon dioxide per minute. | (f) Oxygen per minute. | (g) Respiratory quotient. |
|---|---|---|---|---|---|---|
| | *kg.* | *meters.* | | *c.c.* | *c.c.* | |
| Fis | 75.3 | 69.7 | 5,245 | 713 | 952 | 0.75 |
| Har | 62.5 | 69.3 | 4,431 | 640 | 824 | .78 |
| How | 68.8 | 69.7 | 4,792 | 680 | 852 | .80 |
| Ham | 73.3 | 69.4 | 5,084 | 609 | 835 | .73 |
| Kim | 63.3 | 69.8 | 4,415 | 571 | 742 | .77 |
| Lon | 67.0 | 69.4 | 4,650 | 584 | 721 | .81 |
| Sch | 66.3 | 70.3 | 4,657 | 581 | 747 | .78 |
| Liv | 61.5 | 69.4 | 4,268 | 570 | 744 | .77 |
| Sne | 71.5 | 69.7 | 4,984 | 640 | 836 | .77 |
| Tho | 62.5 | 69.8 | 4,363 | 527 | 660 | .80 |
| Van | 68.0 | 69.7 | 4,740 | 581 | 765 | .76 |
| Wil | 59.3 | 69.8 | 4,136 | 568 | 657 | .87 |
| Average | 66.6 | 69.7 | 4,641 | 605 | 778 | .78 |
| Average[3] | 66.5 | 69.7 | 4,647 | 607 | 783 | .78 |

| (a) Subject. | Heat output per minute (computed). (h) Total. | (i) During standing. | Increase over standing. (j) Total. (h−i). | (k) Per horizontal kg. meter. (j÷d)×1000 | (l) Total heat required in walking 10 km.[1] $\left(\frac{h \times 10{,}000}{c}\right)$ |
|---|---|---|---|---|---|
| | *cals.* | *cals.* | *cals.* | *gm.-cals.* | *cals.* |
| Fis | 4.51 | 1.22 | 3.29 | 0.627 | 647 |
| Har | 3.94 | 1.05 | 2.89 | .652 | 569 |
| How | 4.08 | 1.14[2] | 2.94 | .614 | 585 |
| Ham | 3.93 | 1.19 | 2.74 | .539 | 566 |
| Kim | 3.53 | 1.05 | 2.48 | .562 | 506 |
| Lon | 3.47 | 1.01 | 2.46 | .529 | 500 |
| Sch | 3.56 | 1.10 | 2.46 | .528 | 506 |
| Liv | 3.54 | 1.00 | 2.54 | .596 | 510 |
| Sne | 3.96 | 1.19 | 2.77 | .556 | 568 |
| Tho | 3.16 | 1.01 | 2.15 | .493 | 453 |
| Van | 3.63 | 1.09 | 2.54 | .536 | 521 |
| Wil | 3.21 | 1.09 | 2.12 | .512 | 460 |
| Average | 3.71 | 1.10 | 2.61 | .562 | 533 |
| Average[3] | 3.73 | 1.10 | 2.63 | .565 | 536 |

[1] Equivalent to 4.2 km. (2.6 miles) per hour, at rate of 70 meters per minute.
[2] Computed; see page 535. [3]Omitting Lon.

drawn in table 141 an abstract of the important gaseous and heat measurements for all the members of Squad B at the two nutritional levels.

This table is primarily a comparison table and indicates, in the first place, the pronounced fall in weight which has been discussed in a previous section. All the men lost in weight, the smallest loss being

that with *Kim*, amounting to but 2.3 per cent of his initial body-weight, and the largest with *How*, with 7.0 per cent of his body-weight. The uniformity of the mill is attested by the indication of no appreciable changes in distance walked per minute. The total heat output during standing and the increase above standing show a material falling-off during the 20-day test. As pointed out in a previous section, the

TABLE 141.—*Comparison of the metabolism during walking in treadmill chamber of Squad B normal on January 6, and on January 28 after 20 days restriction in diet, with per cent change from normal.*

[1] Computed; see page 535. [2] Not included in average.

TABLE 142.—*Increase in the heat output during walking in treadmill chamber and the computed total heat required in walking 10 km.—Squad A, 120 days restricted diet, February 3, 1918.*

| (a) Subject. | (b) Weight with clothes, electrodes, etc. | (c) Distance per minute. | (d) Horizontal kg.-meters per minute. ($b \times c$). | (e) Carbon dioxide per minute. | (f) Oxygen per minute. | (g) Respiratory quotient. |
|---|---|---|---|---|---|---|
| | *kg.* | *meters.* | | *c.c.* | *c.c.* | |
| Bro........... | 58.0 | 69.7 | 4,043 | 527 | 659 | 0.80 |
| Can........... | 72.5 | 69.6 | 5,046 | 653 | 789 | .83 |
| Kon........... | 64.8 | 69.3 | 4,487 | 580 | 736 | .79 |
| Gar........... | 66.8 | 69.7 | 4,653 | 596 | 673 | .89 |
| Gul........... | 64.0 | 69.6 | 4,454 | 614 | 665 | .92 |
| Mon........... | 63.8 | 70.0 | 4,463 | 574 | 745 | .77 |
| Moy........... | 60.3 | 70.0 | 4,218 | 557 | 668 | .83 |
| Pea........... | 64.8 | 69.2 | 4,481 | 573 | 744 | .77 |
| Pec........... | 62.5 | 69.6 | 4,350 | 558 | 676 | .83 |
| Tom........... | 58.0 | 69.7 | 4,043 | 529 | 569 | .93 |
| Vea........... | 61.8 | 69.4 | 4,286 | 608 | 743 | .82 |
| Average..... | 63.4 | 69.6 | 4,410 | 579 | 697 | .84 |

| (a) Subject. | Heat output per minute (computed). | | | | (l) Total heat required in walking 10 km.[1] $\left(\frac{h \times 10{,}000}{c}\right)$ |
|---|---|---|---|---|---|
| | (h) Total. | (i) During standing. | Increase over standing. | | |
| | | | (j) Total. ($h-i$). | (k) Per horizontal kg.-meter. $\left(\frac{(j \div d) \times 1000}{}\right)$ | |
| | *cals.* | *cals.* | *cals.* | *gm.-cals.* | *cals.* |
| Bro............. | 3.16 | 1.00 | 2.16 | 0.534 | 453 |
| Can............. | 3.81 | 1.27 | 2.54 | .503 | 547 |
| Kon............. | 3.52 | 1.03 | 2.49 | .555 | 508 |
| Gar............. | 3.31 | 1.22 | 2.09 | .449 | 475 |
| Gul............. | 3.30 | 1.01 | 2.29 | .514 | 474 |
| Mon............. | 3.55 | 1.16 | 2.39 | .536 | 507 |
| Moy............. | 3.23 | 1.11 | 2.12 | .503 | 461 |
| Pea............. | 3.55 | 0.97 | 2.58 | .576 | 513 |
| Pec............. | 3.25 | 0.97 | 2.30 | .529 | 467 |
| Tom............. | 2.82 | 1.00 | 1.82 | .450 | 405 |
| Vea............. | 3.58 | 1.01 | 2.57 | .600 | 516 |
| Average ....... | 3.37 | 1.07 | 2.30 | .522 | 484 |

[1] Equivalent to 4.2 km. (2.6 miles) per hour, at rate of 70 meters per minute.

constants when compared to the normal values in table 139, are seen to be remarkably uniform, varying only from 0.449 with *Gar* to 0.600 with *Vea*.

## COMPARISON OF RESULTS OF WALKING EXPERIMENTS WITH SQUADS A AND B.

The average values found with Squad A and the average normal for Squad B can best be summarized in connection with a review of the comparisons with Squad B before and after reduced diet. These comparisons are made in table 143.

For the reasons given previously, we believe the values for Squad B normal may be properly assumed to represent the values for Squad A normal, and the computations are thus made in table 143. The distance walked remained the same in all tests. The body-weight in all tests decreased. The total heat output required to walk 10 km. decreased with the 12 men of Squad B 14.8 per cent. With the 11 men of Squad A, whose period of reduced diet was much longer with a much greater loss of body-weight, it decreased 22.7 per cent. This decrease represents in both cases a pronounced fall in the total energy requirement for the transportation of the individual over a given distance.

TABLE 143.—*Comparison of the metabolism of Squads A and B on reduced diet with Squad B normal for a basis.*

| Groups of subjects and conditions compared. | Average weight with clothes, electrodes, etc. | Distance walked per minute. | Horizontal kilogram-meters. | Heat output per horizontal kilogram-meter. | Change from Squad B normal. | Total heat required in walking 10 km. | Change from Squad B normal. |
|---|---|---|---|---|---|---|---|
| | *kg.* | *meters.* | | *cals.* | *p. ct.* | *cals.* | *p. ct.* |
| Squad B, normal.. | 70.5 | 69.4 | 4,894 | 0.597[1] | ........ | 626 | ........ |
| Squad B, 20 days.. | 66.6 | 69.7 | 4,641 | .562 | 6.0 | 533 | 14.8 |
| Squad A, 120 days[1] | 63.4 | 69.6 | 4,410 | .522 | 12.6 | 484 | 22.7 |

[1] Average of 11 subjects.

It thus appears that the demonstrated decrease in the metabolism of these individuals, when resting quietly, and when standing quietly, is also noted in walking, and that the organism can walk at much less expenditure of energy with low diet. This of itself is an extremely important practical point. From earlier experiments of Durig and his school, who have studied the effect of superimposed loads, one may reasonably assume that with the reduced diet the individual can not only walk a given distance, but can transport a load equivalent to the loss in body-weight at no greater expenditure of energy than was noted prior to the diet reduction. In this sense there would be a distinct economic gain, for each kilogram of body-weight lost may now be transported in the form of effective external load and the total energy requirement or expenditure not exceed that prior to restriction.

When one considers the organism as a system of levers and attachments for performing muscular work, and that during the process of weight reduction these levers have decreased in weight with, in consequence, a lessened demand for energy for their movement, it can be seen that the lighter the member, other things being equal, the more effective the mechanical operation.

Of special significance, however, is a consideration of the values for the heat output per horizontal kilogrammeter, *i. e.*, for the same

TABLE 144.—*Record of the steps per minute, length of stride, and number of steps per 100 meters for Squads A and B on January 6, 28, and February 3, together with the length of step as computed from the photographic records on the sixth, twelfth, and twenty-fourth minutes of walking.*

| Subject. | Total distance walked. | Steps taken as computed from photographic records. | Average no. of steps per minute. | Average length of steps. | Steps per 100 meters. | Length of step at end of— 1 min. | 6 min. | 12 min. | 24 min. |
|---|---|---|---|---|---|---|---|---|---|
| **SQUAD B, NORMAL, JAN. 6, 1918.** | | | | | | | | | |
| | *meters.* | | | *cm.* | | *cm.* | *cm.* | *cm.* | *cm.* |
| Fis..... | 1,377 | 1,872 | 94 | 74 | 135 | 71.2 | 73.9 | 74.0 | 75.3 |
| Har..... | 1,386 | 1,824 | 91 | 76 | 132 | 77.1 | 79.3 | 74.2 | 73.5 |
| How.... | 1,385 | 1,980 | 99 | 70 | 143 | 73.3 | 69.5 | 70.5 | 67.5 |
| Ham.... | 1,392 | 1,854 | 93 | 75 | 133 | 71.9 | 75.8 | 78.6 | 74.3 |
| Kim.... | 1,397 | 1,880 | 94 | 74 | 135 | 73.8 | 75.8 | 73.6 | 74.4 |
| Sch..... | 1,388 | 1,948 | 97 | 71 | 141 | 66.7 | 73.7 | 72.5 | 73.1 |
| Liv...... | 1,392 | 2,114 | 106 | 66 | 151 | 66.1 | 65.5 | 66.7 | 64.8 |
| Sne..... | 1,382 | 1,946 | 97 | 71 | 141 | 70.0 | 70.7 | 71.3 | 72.3 |
| Tho..... | 1,398 | 1,856 | 93 | 75 | 133 | 75.9 | 75.3 | 75.9 | 74.6 |
| Van..... | 1,388 | 1,845 | 92 | 75 | 133 | ........ | ........ | 74.9 | 75.5 |
| Wil..... | 1,392 | 2,112 | 106 | 66 | 151 | 64.6 | 66.2 | 68.2 | 64.8 |
| Avg... | 1,389 | 1,932 | 97 | 72 | 139 | 71.1 | 72.6 | 72.8 | 71.8 |
| **SQUAD B, 20 DAYS, JAN. 28, 1918.** | | | | | | | | | |
| | *meters.* | | | *cm.* | | | *cm.* | *cm.* | *m.* |
| Fis..... | 1,394 | 1,824 | 91 | 76 | 132 | ........ | 75.6 | 77.0 | 76.8 |
| Har..... | 1,386 | 1,822 | 92 | 75 | 133 | ........ | ........ | 75.4 .. | ........ |
| Ham.... | 1,388 | 1,940 | 97 | 72 | 139 | ........ | 73.6 | 73.1 .. | ........ |
| Kim.... | 1,396 | 2,038 | 102 | 69 | 145 | ........ | 68.2 | 68.5 | 68.8 |
| Sch..... | 1,406 | 2,016 | 101 | 70 | 143 | ........ | 74.8 | 70.1 | 68.1 |
| Liv...... | 1,388 | 2,204 | 110 | 63 | 159 | ........ | 63.1 | 63.9 | 61.8 |
| Sne..... | 1,394 | 1,974 | 99 | 71 | 141 | ........ | 71.2 | 69.8 | 70.9 |
| Tho..... | 1,395 | 1,970 | 99 | 71 | 141 | ........ | 70.0 | ...... | 71.8 |
| Van..... | 1,394 | 1,944 | 97 | 72 | 139 | ........ | ........ | ...... | 71.9 |
| Wil..... | 1,396 | 2,210 | 111 | 63 | 159 | ........ | 63.0 | 64.2 | 62.1 |
| Avg... | 1,394 | 1,994 | 100 | 70 | 143 | ........ | 69.9 | 70.3 | 69.0 |
| **SQUAD A, 120 DAYS, FEB. 3, 1918.** | | | | | | | | | |
| | *meters.* | | | *cm.* | | | *cm.* | *cm.* | *cm.* |
| Bro..... | 1,394 | 2,006 | 100 | 70 | 143 | ........ | 68.4 | ...... | 70.7 |
| Can..... | 1,392 | 1,974 | 99 | 71 | 142 | ........ | 69.6 | 70.5 | 22′ 24′<br>70.9 71.0 |
| Gar..... | 1,394 | 1,962 | 98 | 71 | 141 | ........ | 71.1 | 71.0 | 71.2 |
| Gul..... | 1,392 | 2,004 | 100 | 69 | 144 | ........ | 4′ 6′<br>68.2 69.4 | 8′<br>68.8 | 20′<br>70.9 |
| Kon.... | 1,386 | 2,160 | 108 | 64 | 156 | ........ | 63.1 | 62.9 | 66.5 |
| Mon.... | 1,400 | 1,986 | 99 | 71 | 142 | ........ | 69.6 | 71.5 | ........ |
| Moy.... | 1,399 | 1,876 | 94 | 75 | 134 | ........ | 73.5 | 74.4 | 75.8 |
| Pea..... | 1,384 | 2,190 | 109 | 63 | 158 | ........ | 61.5 | 63.3 | 64.9 |
| Pec..... | 1,391 | 2,186 | 109 | 64 | 157 | ........ | 63.6 | 63.9 | 63.2 |
| Tom.... | 1,394 | 2,000 | 100 | 70 | 144 | ........ | 69.3 | 70.1 | 69.7 |
| Vea..... | 1,387 | 1,934 | 97 | 72 | 139 | ........ | 72.0 | 71.5 | 73.2 |
| Avg... | 1,392 | 2,025 | 101 | 69 | 146 | ........ | 68.3 | 68.8 | 69.7 |

the average of the groups considerably. However, the two measurements W and R employed in measuring the body-surface area of the men on January 27 and February 2 (see pp. 234-237), show that the difference in length of leg was slight, the length for Squad B averaging 89.7 cm. and that for Squad A 88.7 cm. The averages of the two groups are accordingly compared in table 145 which shows the decrease in the average length of stride and the increase in the number of steps per minute and per meter for the three tests.

TABLE 145.—*Comparison of average of distance walked, steps taken, and length of step of Squads B, normal, B 20-day, and A 120-day during walking in the treadmill chamber.*

| Groups of subjects and conditions compared. | Distance walked. | Steps taken. | Av. steps per min. | Av. length per step. | Steps per 100 meters. |
|---|---|---|---|---|---|
| | *km.* | | | *cm.* | |
| Squad B, normal..... | 1,389 | 1,932 | 97 | 72 | 139 |
| Squad B, 20 days..... | 1,394 | 1,994 | 100 | 70 | 143 |
| Squad A, 120 days.... | 1,392 | 2,025 | 101 | 69 | 146 |

How close may be the connection between these results and the lowering of the heat output per horizontal kilogrammeter is uncertain. That it may have some bearing is reasonable to suppose. Not a little of the actual work of forward progression consists of lifting the body on the toes as one leg is swung past the other. Benedict and Murschhauser[1] published some measurements on this toe-lift and found that their Subject I, who weighed 73.1 kg., in walking at a rate of 75.9 meters per minute, lifted the body on the average 3.78 meters per minute, which was equivalent to 0.65 large calorie, or 23 per cent of the increase over the standing metabolism.

Jendrássik[2] has shown that in horizontal walking the body is held longer in equilibrium on one foot, while in grade walking the equilibrium is maintained longer on both feet. It is possible that in these experiments, with a lowered nutritional level, the body endeavored to spare itself the effort of maintaining equilibrium on one foot and excessive toe-lift, and found in a shorter and quicker step a means to this end. It is, at least, an interesting coincidence that *Fis* and *Sne*, who showed no decrease in length of stride nor increase in number of steps per 100 meters on January 28 over January 6, both showed an increase in the heat output per horizontal kilogrammeter. The cases of *Har* and *Liv*, who also showed increased cost per horizontal kilogrammeter, are in contrast to the behavior of these two.

[1] Benedict and Murschhauser, Carnegie Inst. Wash. Pub. No. 231, 1915, p. 80.
[2] Jendrássik, Arch. f. Phys., 1904, Supp. Band, p. 287.

*Pea, Pec, Tom,* and *Vea.* The values for *Kon, Spe,* and *Fre* will be given when they exist and may be compared, but are not included in the group average. The average result for Squad B will be the average of the individual records for the following 10 subjects: *Fis, Har, How, Ham, Lon, Liv, Sne, Tho, Van,* and *Wil.* The individual values, when available, will be given for *McM, Kim, Mac,* and *Sch.* It will be of interest to note occasionally how far the fragmentary records of the other subjects conform to the general findings for the group.

Although the amount of time devoted to any one measurement on an individual in an evening or morning session was rather limited, the apparatus and procedure had been arranged with a view to taking several observations of that particular kind, so that their average would be a fairly good sample of the individual's performance in that process or function. In illustration of this it will be seen as explained in the section on program and technique (p. 137) that in the measurements of the eye reactions, the word reactions, the eye movements, and the electrical threshold, particular attention had been paid to this matter. It was desired that the number of observations of a particular kind on one subject should be large enough so that some statement statistically significant regarding their consistency and uniformity might be given. When practicable, the standard deviation and coefficient of variability[1] for the individual subject and for each experiment are included in the tables, and these individual variability measures are averaged as are the other results.

We are glad to take this opportunity of acknowledging the faithful services of Miss Anna Berlin and Mr. Edward S. Mills in reading the records and in many of the computations for the large amount of psychological data.

The date on which each neuro-muscular measurement was given for the first time to the members of the two squads can be found in the chronological record of the whole experiment (p. 60). It will be further observed that for Squad B the first and second sessions (October 6 and November 3) and the third and fourth (November 17 and December 15) were in each case separated by 4 weeks. Between the fourth and fifth sessions (December 15 and January 5) there was an interval of 3 weeks. The others were separated by 2 weeks or less. All of the night observations were on Saturdays except those on January 13 and 27, which were on Sundays. January 5 was an unfavorable date experi-

[1] The standard deviation was computed by the usual formula:—$S.D.$ or $\sigma = \sqrt{\frac{\Sigma(d^2)}{n}}$. In order to compare the variability in the results for one measurement with that in a series of observations of another process, it is desirable to know the relative size of the two variability measures in terms of per cent of their respective averages or other central tendency measures. In the following tables the coefficient of variability, $C = \frac{S.D.}{M.}$ is employed, in which $S.D.$ is the standard deviation and $M$ the arithmetical average. (See Whipple, Manual of Mental and Physical Tests, Part I, Baltimore, 1914, p. 24.)

those for the 9 days, mostly because they include the uncontrolle Sundays, which were the farthest possible removed from the psycho logical sessions.

The individual energy values in table 146 are lowest on November 10 This general average of 1,390 calories is higher, however, on account o the standard evening meal than the energy for the two preceding days November 8 and 9. The reverse will be found true if a like compariso is made for December 19. Thus the constant factor of the standar meals taken before the psychological tests minimizes the fluctuation and tends to place all the psychological results on a more comparabl and uniform level.

TABLE 146.—*Net available calories per man on those days when the members of Squad A cam to Boston and had evening psychological tests.*

[1] This average does not include *Kon*, *Spe* and *Fre*.
[2] Assumed from average calories for normal period Oct. 1–4.
[3] For above nine days during reduced-diet period.
[4] For whole reduced-diet period exclusive of Thanksgiving and Christmas vacations.

those with A. It is, furthermore, unfortunate that the last normal date for this squad (January 5) was the immediate close of the vacation period and was separated from their previous experiment by 3 weeks. The conditions in the two observations preceding the food reduction with Squad B are not favorable for revealing the influence of the 3 weeks of reduced diet. Notwithstanding this, it is evident from the curve in figure 102 that up to the sixth experiment, in spite of the longer intervals between experiments, Squad B shows a superior performance to Squad A. At the sixth experiment, the first in the reduced-diet period for Squad B, they are slightly poorer than Squad A, and in their next two, January 19 and 27, while they improve over January 13, they do not reach the record of Squad A for January 26 and February 2, which, considering their superiority over Squad A in experiments 2 to 5 inclusive, they might reasonably have been expected to reach.

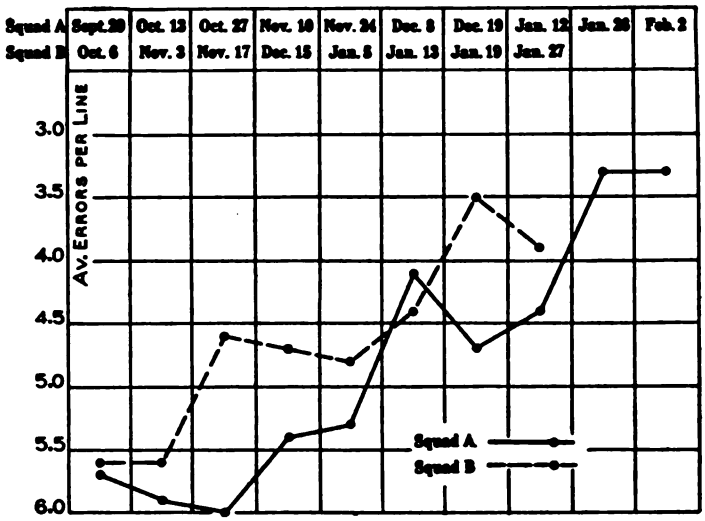

FIG. 102.—Errors in accuracy of tracing between parallel lines.

It seems justifiable to conclude, although the results for Squad B, unless interpreted in the light of certain modifying conditions, will not entirely support the statement, that with Squad A, particularly during the months of October and November, the motor functions involved in steadiness in tracing as used in this test were interfered with by the reduced diet, since the squad as a whole did not do such accurate work or make such rapid improvement in the test as would have been expected of them under normal conditions.

(2) DISCRIMINATION FOR THE PITCH OF TONES.

Seashore and his collaborators[1] have concluded as a result of a great deal of experimentation that the ability to discriminate the pitch of tones is elemental and the sensitiveness of the ear to pitch dif-

[1] Seashore, Psychological Monographs, 1910, 13, p. 53; Smith, F. O. (Iowa Studies in Psychology, 6), Psychological Monographs, 1914, 16, pp. 67 to 103, particularly p. 101; Seashore and Mount (Iowa Studies in Psychology, 7), Psychological Monographs, 1918, 15, pp. 47 to 92; also, Seashore and Tan, *ibid.*, pp. 159 to 163.

ferences can not be improved appreciably by practice. They di tinguish sharply between the cognative and physiological threshold The cognative threshold shows rapid improvement at first and a proaches the physiological threshold just to that degree that t subject is able to grasp the nature of the test, to understand thorough what is required of him, remove subjective disturbances, expectation and inhibitions, and to summon his best effort and most favorab attention to the discrimination of the *pitch* of the tones presented.

These experimenters believe that a 1-hour group test by the heter geneous method (that is, a number of individuals who have not be classified in reference to their pitch discrimination ability, tested wi a number of pitch differences ranging in size from 30 to 1 vd.,[1] a each increment presented for judgment about an equal number times) will reveal the approximate physiological threshold of abo half of the subjects tested. The elimination of all objective distur ances, careful instruction, and the ingenuity of the experiment count for much.

In using pitch discrimination as a measurement in the prese research, it was not hoped to make an accurate determination of t physiological threshold of the subjects tested to ascertain if foo reduction changed this physiological constant. The time would n permit of using the measurement in any other way than by the grou method. In the first test with each squad pitch difference incr ments of 30, 23, 17, 12, 8, 5, 3, 2, and 1 vd. lower than 435 vd. we employed. The test lasted about one-half hour. Judging by pr vious experience with pitch discrimination measurements, the cond tions were favorable. Nearly all the subjects were able to discriminat without error, differences above 8 vd. In succeeding tests it was ther fore possible to confine the judgments to intervals of 8, 5, 3, 2, and 1 v It would have been possible also to have omitted the increment 8 vd., since nearly all subjects show from 90 to 100 per cent corre judgment with this pair of tuning forks. It was, however, adva tageous to use this increment in the test because of the easy assuranc with which the subject was able to judge between these tones. Th gave confidence for the more difficult judgments.

In tables 149 and 150 for Squads A and B, respectively, the pe centages of correct judgments are given for the pitch increments 3, 2, and 1 vd.[2] The tables are of the same general form as those give for steadiness of tracing. Thus in table 149 *Bro* on October 13 show 97 per cent correct judgment with a pitch difference of 5 vd., 90 p cent with a difference of 3, 80 per cent for 2, and 63 per cent for a di ference of 1 vd. This was the second trial in pitch discriminatio

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[1] Double vibrations.

[2] It appeared unnecessary to include the results for 8 vd., as the percentage of correct judgme with this interval was usually well above 90.

for this subject, and his record shows considerable improvement for the same pitch increments over his trial on September 29, when, as described, the larger increments were used and fewer trials were made with each. There are a large number of values scattered through the

TABLE 149.—*Squad A—Percentage of correct judgments in pitch discrimination.*

[illegible]

[1] Records for *Mon* show low and irregular values and were not included in the average which also excludes *Kon*, *Spe*, and *Fre*.
[2] Sept. 29 (normal) not included in this average.

table that show 100 per cent correct judgment. These are usuall with increments of 5 and 3 vd. *Gul* had a final average (see averag at bottom of table 149) of 100 per cent correct judgment with 5 vd. 99 per cent with 3, with 91 per cent and 77 per cent for 2 and 1 vd respectively. Conventionally, the pitch discrimination threshold i considered to be that difference or increment which shows 75 per cen of correct judgment. According to this, *Gul's* threshold was 1 vc

TABLE 150.—*Squad B—Percentage of correct judgments in pitch discrimination.*

| Date. | Intervals. | Fis. | Har. | How. | Ham. | McM. | Kim. | Lon. | Mac. | Sch. | Liv. | Sne. | Tho. | Van.[1] | Wil. | Av.[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. | *vd.* | | | | | | | | | | | | | | | |
| Oct. 6.. | 5 | 70 | 80 | 60 | 90 | .... | .... | 80 | 90 | .... | 80 | 80 | 90 | 80 | 100 | 81 |
| | 3 | 70 | 80 | 80 | 50 | .... | .... | 40 | 70 | .... | 70 | 90 | 90 | 60 | 100 | 74 |
| | 2 | 70 | 70 | 60 | 80 | .... | .... | 60 | 60 | .... | 60 | 60 | 80 | 50 | 90 | 70 |
| | 1 | 50 | 40 | 60 | 50 | .... | .... | 40 | 40 | .... | 60 | 60 | 70 | 10 | 80 | 57 |
| Nov. 3.. | 5 | 90 | 80 | 87 | 90 | 77 | .... | 93 | 87 | .... | 83 | 93 | 100 | 43 | 100 | 91 |
| | 3 | 83 | 93 | 73 | 83 | 70 | .... | 87 | 87 | .... | 67 | 77 | 97 | 17 | 100 | 84 |
| | 2 | 77 | 77 | 50 | 53 | 87 | .... | 67 | 70 | .... | 57 | 70 | 90 | 30 | 83 | 69 |
| | 1 | 63 | 57 | 40 | 53 | 60 | .... | 47 | 60 | .... | 50 | 60 | 67 | 33 | 83 | 58 |
| Nov. 17.. | 5 | 97 | 90 | 90 | 97 | 47 | .... | 100 | 97 | .... | 87 | 100 | 100 | 70 | 100 | 96 |
| | 3 | 87 | 93 | 80 | 80 | 47 | .... | 83 | 93 | .... | 83 | 93 | 97 | 40 | 100 | 88 |
| | 2 | 67 | 77 | 73 | 73 | 50 | .... | 70 | 67 | .... | 70 | 83 | 93 | 33 | 90 | 77 |
| | 1 | 50 | 73 | 43 | 43 | 37 | .... | 47 | 40 | .... | 43 | 57 | 67 | 37 | 87 | 57 |
| Dec. 15.. | 5 | .... | 77 | 73 | 80 | 57 | .... | 100 | 97 | .... | 87 | 97 | 100 | 77 | 100 | 8[illegible] |
| | 3 | .... | 80 | 67 | 80 | 53 | .... | 87 | 90 | .... | 67 | 93 | 87 | 57 | 100 | 8[illegible] |
| | 2 | .... | 73 | 60 | 70 | 47 | .... | 70 | 70 | .... | 70 | 73 | 83 | 37 | 97 | 7[illegible] |
| | 1 | .... | 67 | 47 | 60 | 40 | .... | 57 | 53 | .... | 70 | 77 | 77 | 47 | 90 | 6[illegible] |
| 1918. | | | | | | | | | | | | | | | | |
| Jan. 5.. | 5 | 97 | 93 | 97 | 97 | 57 | 100 | .... | .... | 67 | 83 | 93 | .... | 70 | 93 | 9[illegible] |
| | 3 | 77 | 80 | 90 | 70 | 47 | 100 | .... | .... | 67 | 83 | 87 | .... | 67 | 97 | 8[illegible] |
| | 2 | 63 | 77 | 73 | 67 | 60 | 77 | .... | .... | 57 | 63 | 67 | .... | 70 | 90 | 7[illegible] |
| | 1 | 67 | 80 | 67 | 60 | 53 | 57 | .... | .... | 60 | 50 | 77 | .... | 57 | 73 | 6[illegible] |
| Normal av... | 5 | 88 | 84 | 81 | 91 | 60 | 100 | 93 | 93 | 67 | 84 | 93 | 98 | 68 | 99 | 9[illegible] |
| | 3 | 79 | 85 | 78 | 73 | 54 | 100 | 74 | 85 | 67 | 74 | 88 | 93 | 48 | 99 | 8[illegible] |
| | 2 | 69 | 75 | 63 | 69 | 61 | 77 | 67 | 67 | 57 | 54 | 71 | 87 | 46 | 71 | 7[illegible] |
| | 1 | 58 | 63 | 53 | 53 | 48 | 57 | 48 | 48 | 60 | 55 | 66 | 70 | 37 | 83 | 6[illegible] |
| Jan. 13.. | 5 | 93 | 80 | 97 | 100 | .... | 100 | 97 | .... | 50 | 90 | 93 | 100 | 83 | 100 | 9[illegible] |
| | 3 | 87 | 80 | 83 | 80 | .... | 100 | 73 | .... | 40 | 93 | 100 | 87 | 60 | 97 | 8[illegible] |
| | 2 | 83 | 60 | 63 | 87 | .... | 90 | 60 | .... | 50 | 70 | 80 | 53 | 57 | 93 | 7[illegible] |
| | 1 | 60 | 50 | 50 | 47 | .... | 70 | 57 | .... | 53 | 57 | 53 | 63 | 73 | 87 | 5[illegible] |
| Jan. 19.. | 5 | 100 | 90 | 87 | 83 | .... | 100 | 83 | .... | 73 | 90 | 97 | 93 | 80 | 100 | [illegible] |
| | 3 | 90 | 100 | 73 | 73 | .... | 100 | 70 | .... | 37 | 80 | 97 | 97 | 80 | 100 | [illegible] |
| | 2 | 70 | 60 | 50 | 67 | .... | 83 | 50 | .... | 43 | 43 | 80 | 67 | 83 | 100 | [illegible] |
| | 1 | 63 | 57 | 60 | 47 | .... | 63 | 50 | .... | 37 | 60 | 70 | 43 | 53 | 90 | [illegible] |
| Jan. 27.. | 5 | 100 | 97 | 80 | 90 | .... | 100 | 93 | .... | 60 | 97 | 100 | 100 | 90 | 100 | [illegible] |
| | 3 | 90 | 90 | 77 | 70 | .... | 93 | 40 | .... | 50 | 77 | 90 | 93 | 60 | 100 | [illegible] |
| | 2 | 77 | 83 | 63 | 63 | .... | 93 | 47 | .... | 40 | 53 | 73 | 73 | 43 | 77 | [illegible] |
| | 1 | 70 | 67 | 63 | 50 | .... | 70 | 57 | .... | 43 | 43 | 80 | 70 | 57 | 60 | [illegible] |
| Low-diet av... | 5 | 98 | 89 | 88 | 91 | .... | 100 | 91 | .... | 61 | 92 | 97 | 98 | 84 | 100 | [illegible] |
| | 3 | 89 | 90 | 78 | 74 | .... | 98 | 61 | .... | 42 | 83 | 96 | 92 | 67 | 99 | [illegible] |
| | 2 | 77 | 68 | 59 | 72 | .... | 89 | 52 | .... | 44 | 55 | 78 | 64 | 61 | 90 | [illegible] |
| | 1 | 64 | 58 | 58 | 48 | .... | 68 | 55 | .... | 44 | 53 | 68 | 59 | 61 | 79 | [illegible] |

[1] Besides *McM*, *Kim*, *Mac*, and *Sch*, subject *Van* is also excluded from this average, as he sh low and irregular values.

*Har* and *How* of 77 and 73 per cent (see table 150), which are considerably lower than usual for these two subjects. From the fifth session to the close of the experiment the two squads show uniform results.

With 3 vd., improvement is evident between the first and second experiments, Squad B indicating about the same improvement as with 5 vd. Squad A shows considerable improvement, but this is due to the unexplainable fact that the threshold for 3 vd. on September 29 was abnormally low. The record for several of the subjects, *i. e.*, *Bro*, *Moy*, *Gar*, *Tom* and *Vea*, is only 50 to 60 per cent correct judgment (see table 149). Some improvement is evident in the next two sessions (experiments 3 and 4). The decline in experiment 5 of itself is perhaps not significant, but it is the beginning of the depression in the curve during the next four sessions, that is, December 8 to January

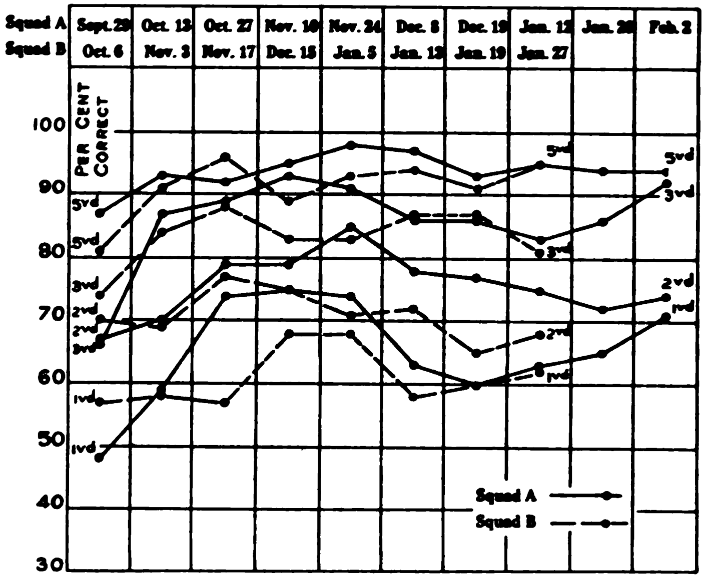



FIG. 103.—Percentage of correct judgments in discriminating the pitch of tones.

26, which is fairly well marked. There is recovery to the highest level on February 2. Squad B shows depression for 3 vd. on December 15 and January 5, that is, just before and just following the Christmas vacation, with a drop on January 27.

For 2 vd. the curves start at about the same level; there is almost no improvement between the first and second experiments; there is, however, considerable improvement between the second and third experiments. Specifically, Squad A continued to improve after this date and reached their highest value on November 24. From December 8 to the end of the experiment there was a decrement. Squad B showed a decrease on January 5, to a score of 71 per cent. January 13, the first

ure of the amount of material covered and depends upon the speed and accuracy of each subject. Tables 151 and 152 give the individual data for all the subjects of Squads A and B. The tables are arranged in the usual form, with the dates in chronological order at the left, and column headings giving the subjects in order. The breaks discussed on page 557 likewise occur in these data. Incorrect combinations were marked by members of either squad in only a few instances, as with

TABLE 151.—*Squad A—Cancellation of specified number groups.*

| Date and number groups. | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pea. | Pec. | Spe. | Tom. | Ves. | Fre. | Av.[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. | | | | | | | | | | | | | | |
| Sept. 29: | | | | | | | | | | | | | | |
| Found............ | 28 | 26 | 23 | 27 | 47 | 37 | 25 | 48 | 25 | 10 | 40 | 44 | 34 | 34.7 |
| Missed............ | 8 | 17 | 5 | 2 | 30 | 19 | 4 | 16 | 15 | 5 | 4 | 20 | 10 | 13.5 |
| Mistakes.......... | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | .3 |
| Oct. 13: | | | | | | | | | | | | | | |
| Found............ | 56 | 39 | .... | 40 | 76 | 65 | 43 | 63 | 45 | 30 | 50 | 72 | 59 | 54.9 |
| Missed............ | 14 | 26 | .... | 51 | 64 | 20 | 10 | 26 | 28 | 9 | 20 | 16 | 29 | 27.5 |
| Mistakes.......... | 0 | 4 | .... | 3 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 1.1 |
| Oct. 27: | | | | | | | | | | | | | | |
| Found............ | 68 | 49 | 44 | 60 | 89 | 68 | 51 | 80 | 61 | 39 | 47 | 78 | .... | 65.1 |
| Missed............ | 12 | 7 | 15 | 11 | 50 | 13 | 8 | 25 | 26 | 2 | 7 | 10 | .... | 16.9 |
| Mistakes.......... | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | .... | .2 |
| Nov. 10: | | | | | | | | | | | | | | |
| Found............ | 65 | 60 | 56 | 62 | 77 | 78 | 43 | 88 | 55 | 33 | 53 | 84 | .... | 66.5 |
| Missed............ | 6 | 12 | 5 | 6 | 28 | 9 | 14 | 14 | 27 | 10 | 10 | 21 | .... | 14.7 |
| Mistakes.......... | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .... | .4 |
| Nov. 24: | | | | | | | | | | | | | | |
| Found............ | 75 | 65 | 62 | 67 | 96 | 73 | 41 | 91 | 62 | 34 | 56 | 100 | .... | 72.6 |
| Missed............ | 3 | 13 | 3 | 10 | 62 | 25 | 26 | 8 | 22 | 4 | 11 | 6 | .... | 18.6 |
| Mistakes.......... | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | .... | .6 |
| Dec. 8: | | | | | | | | | | | | | | |
| Found............ | 81 | 71 | 65 | 67 | 121 | 72 | 59 | 82 | 70 | 45 | 60 | 85 | .... | 76.8 |
| Missed............ | 5 | 15 | 7 | 10 | 24 | 30 | 11 | 7 | 17 | 9 | 12 | 4 | .... | 13.5 |
| Mistakes.......... | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .... | .1 |
| Dec. 19: | | | | | | | | | | | | | | |
| Found............ | 80 | 70 | 68 | 72 | 113 | 75 | 54 | 89 | 68 | .... | 60 | 98 | .... | 77.9 |
| Missed............ | 4 | 7 | 4 | 14 | 29 | 21 | 24 | 18 | 20 | .... | 13 | 6 | .... | 15.6 |
| Mistakes.......... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .... | 0 | 0 | .... | 0 |
| 1918. | | | | | | | | | | | | | | |
| Jan. 12: | | | | | | | | | | | | | | |
| Found............ | 79 | 69 | 66 | 72 | 76 | 71 | 56 | 76 | 61 | .... | 60 | 107 | .... | 72.7 |
| Missed............ | 4 | 13 | 5 | 7 | 82 | 37 | 14 | 13 | 23 | .... | 14 | 11 | .... | 21.8 |
| Mistakes.......... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .... | 0 | 0 | .... | 0 |
| Jan. 26: | | | | | | | | | | | | | | |
| Found............ | 89 | 75 | 72 | 75 | 119 | 77 | 58 | 101 | 68 | .... | 65 | 106 | .... | 83.3 |
| Missed............ | 4 | 14 | 12 | 9 | 34 | 22 | 14 | 8 | 19 | .... | 22 | 13 | .... | 15.9 |
| Mistakes.......... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .... | 0 | 0 | .... | 0 |
| Feb. 2: | | | | | | | | | | | | | | |
| Found............ | 98 | 71 | 77 | 79 | 118 | 83 | 71 | 106 | 74 | .... | 75 | 115 | .... | 89.0 |
| Missed............ | 2 | 14 | 4 | 7 | 25 | 22 | 10 | 16 | 17 | .... | 17 | 4 | .... | 13.4 |
| Mistakes.......... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .... | 0 | 0 | .... | 0 |
| Low-diet av.: | | | | | | | | | | | | | | |
| Found............ | 76.8 | 63.2 | 83.8 | 66.0 | 98.3 | 73.6 | 52.9 | 86.2 | 62.7 | 36.2 | 58.4 | 93.9 | 59 | 73.2 |
| Missed............ | 6.0 | 13.4 | 6.9 | 13.9 | 44.2 | 22.1 | 14.6 | 15.0 | 22.1 | 6.8 | 14.0 | 10.1 | 29 | 17.5 |
| Mistakes.......... | 0 | 1.4 | 0 | .3 | 0 | 0 | .4 | 0 | 0 | 0 | .4 | 0 | 0 | .3 |

[1]These averages do not include the records for *Kon*, *Spe*, and *Fre*.

quite regularly in the of his test. *Gul* shows a mark
number of
more
score 100
it was Two lower
January Almo
a month the t
men were a very reduction in diet at this tim

*of specified number groups.*

[1] These averages do not include the records of *McM*, *Kim*, *Mac*, and *Sch*.

The average for the 10 regular subjects of Squad A (see right-hand column of table 153) shows a rapid and uninterrupted improvement except on January 12.

Squad B, table 154, shows the same general result with this test. In the five normal experiments all the subjects improved regularly, with the exception of a small relapse on the part of some subjects, for example, *How*, *Ham*, *McM*, *Sne* and *Wil* on December 15. In the normal averages *Wil* and *Van* lead with scores of 58.4 and 55.4, respec-

TABLE 153.—*Squad A—Efficiency scores for cancellation of number groups.*

TABLE 154.—*Squad B—Efficiency scores for cancellation of number groups.*

tively. Several subjects have scores of 40 and above. These in order of rank would be *Har*, *Lon*, *Sne*, *Liv*, *Ham*, and *Tho*. In the low-diet period each subject for whom records are complete shows an average above his normal. In the case of *Sch*, who only had one normal experiment (January 5) there was no improvement and, in fact, a slight decrement during the reduction period. This subject omitted a large number. (See record for January 27.) In the low-diet period the highest average was that of *Van*, 83.3, an increase of 27.9

over his normal average. Two other subjects, *Har* and *Liv*, ma
increases above 20, but on the average the improvement during t
3 weeks of the reduced diet was small, there being hardly any on Ja
uary 13 and 19.

The general averages for the two squads are plotted in figure 10
The main interruption in the improvement shown by Squad A was
January 12, as previously mentioned. Considering the points fro
which the two squads start, each improved approximately the sa
amount. The curves are regular and of the usual practice form.
will be noted that Squad A, on their one normal date, were at a high
level than Squad B, the difference being 10 points in favor of Squad

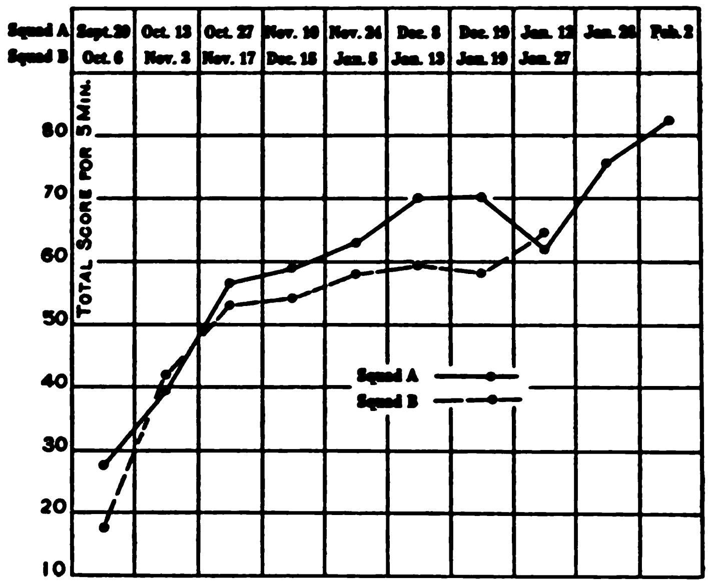



FIG. 104.—Efficiency in the cancellation of specified number-groups.

In the two succeeding experiments, however, which were during r
duced diet, Squad A failed to maintain this advantage and improve
relatively slower than Squad B. During the low-diet period, Squad
also made but a minor improvement, almost all of which was on t
last date. It appears, therefore, from the data at hand, that im
provement in efficiency for quickly and accurately locating and ca
celling desired number combinations in heterogeneous material is n
favored by the condition of reduced diet.

### (4) ADDITION OF ONE-PLACE NUMBERS.

In an adding experiment when a time limit is used and the uni
in the task are as large as those employed here, that is, columns
10 digits each, in which each column is added and the sum recorde
separately, it must inevitably happen that when the signal to sto

TABLE 155.—*Squad A—Results in 10-minute addition test.*

| Date. | Columns. | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pea. | Pec. | Spe. | Tom. | Ves. | Fre. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept. 29...... | Correct..... | 42 | 24 | 30 | 34 | 33 | 46 | 25 | 51 | 33 | 10 | 56 | 31 | 86 | 37. |
| | P. ct. errors. | 16.0 | 20.0 | 14.3 | 15.0 | 25.0 | 14.8 | 41.9 | 15.0 | 31.3 | 54.6 | 9.7 | 26.2 | 10.4 | 21. |
| Oct. 13...... | Correct..... | 48 | 27 | .... | 35 | 38 | 51 | 34 | 53 | 35 | 20 | 56 | 34 | 76 | 41. |
| | P. ct. errors. | 0.0 | 10.0 | .... | 2.8 | 22.4 | 16.4 | 26.1 | 13.1 | 40.7 | 28.6 | 13.8 | 27.7 | 5.0 | 17. |
| Oct. 27...... | Correct..... | 49 | 22 | 33 | 33 | 40 | 43 | 31 | 58 | 53 | 17 | 57 | 36 | .... | 42. |
| | P. ct. errors. | 3.9 | 33.3 | 15.4 | 15.4 | 24.5 | 18.9 | 35.4 | 10.8 | 11.7 | 37.0 | 10.9 | 25.0 | .... | 19. |
| Nov. 10...... | Correct..... | 46 | 29 | 36 | 38 | 45 | 42 | 38 | 56 | 49 | 22 | 64 | 45 | .... | 45. |
| | P. ct. errors. | 4.2 | 17.2 | 12.2 | 11.6 | 25.0 | 26.3 | 20.8 | 16.4 | 19.7 | 26.6 | 8.6 | 11.8 | .... | 16. |
| Nov. 24...... | Correct..... | 47 | 21 | 35 | 36 | 49 | 46 | 39 | 60 | 50 | 13 | 61 | 40 | .... | 44. |
| | P. ct. errors. | 6.0 | 27.6 | 18.6 | 12.2 | 18.3 | 13.2 | 20.4 | 14.3 | 12.3 | 51.8 | 14.1 | 13.0 | .... | 15 |
| Dec. 8...... | Correct..... | 50 | 22 | 36 | 33 | 49 | 45 | 32 | 54 | 54 | 22 | 64 | 36 | .... | 43 |
| | P. ct. errors. | 3.8 | 24.2 | 16.3 | 5.7 | 21.0 | 16.7 | 36.0 | 10.0 | 19.4 | 31.2 | 9.9 | 23.4 | .... | 17 |
| Dec. 19...... | Correct..... | 50 | 27 | 36 | 38 | 48 | 46 | 34 | 55 | 63 | .... | 64 | 38 | .... | 46 |
| | P. ct. errors. | 5.7 | 15.6 | 14.3 | 2.6 | 23.8 | 16.4 | 37.0 | 14.1 | 13.7 | .... | 9.9 | 22.4 | .... | 16 |
| Jan. 12...... | Correct..... | 49 | 27 | 37 | 32 | 52 | 47 | 27 | 56 | 61 | .... | 59 | 45 | .... | 45 |
| | P. ct. errors. | 2.0 | 12.9 | 7.5 | 11.1 | 21.2 | 16.0 | 37.2 | 8.2 | 10.3 | .... | 7.8 | 15.1 | .... | 14 |
| Jan. 26...... | Correct..... | 48 | 24 | 39 | 32 | 57 | 47 | 41 | 66 | 48 | .... | 65 | 38 | .... | 46 |
| | P. ct. errors. | 7.7 | 22.6 | 13.3 | 5.9 | 12.3 | 7.8 | 21.2 | 0.0 | 25.0 | .... | 7.1 | 22.4 | .... | 13 |
| Feb. 2...... | Correct..... | 51 | 29 | 42 | 39 | 62 | 45 | 43 | 67 | 55 | .... | 66 | 45 | .... | 50 |
| | P. ct. errors. | 5.6 | 19.4 | 10.6 | 4.9 | 12.7 | 15.1 | 14.0 | 6.9 | 20.3 | .... | 8.3 | 10.0 | .... | 11 |
| Low-diet av... | Correct..... | 48.7 | 25.3 | 36.8 | 35.1 | 48.9 | 45.8 | 35.4 | 58.3 | 52.0 | 18.8 | 61.8 | 39.7 | 76.0 | 45 |
| | P. ct. errors. | 4.3 | 20.3 | 13.5 | 8.0 | 20.1 | 16.3 | 27.6 | 10.4 | 19.2 | 35.0 | 10.0 | 19.0 | 5.0 | 15 |

TABLE 156.—*Squad B—Results in 10-minute addition test.*

| Date. | Columns. | Fis. | Har. | How. | Ham. | McM. | Kim. | Lon. | Mac. | Sch. | Liv. | Sne. | Tho. | Van. | Wil. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 6.. | Correct..... | 27 | 19 | 61 | 33 | .... | .... | 42 | 43 | .... | 22 | 27 | 80 | 33 | 49 |
| | P. ct. errors. | 18.2 | 29.6 | 7.6 | 15.4 | .... | .... | 26.3 | 6.5 | .... | 31.2 | 32.5 | 3.6 | 15.4 | 17.0 |
| Nov. 3.. | Correct..... | 31 | 24 | 69 | 36 | 13 | .... | 41 | 51 | .... | 25 | 33 | 86 | 28 | 47 |
| | P. ct. errors. | 3.0 | 4.0 | 9.2 | 14.3 | 41.0 | .... | 10.9 | 5.6 | .... | 16.7 | 8.3 | 5.5 | 22.2 | 14.5 |
| Nov. 17.. | Correct..... | 34 | 23 | 76 | 37 | 14 | .... | 48 | 55 | .... | 31 | 30 | 91 | 37 | 43 |
| | P. ct. errors. | 0.0 | 11.5 | 1.3 | 7.5 | 51.7 | .... | 14.3 | 0.0 | .... | 3.1 | 9.1 | 7.1 | 9.8 | 14.0 |
| Dec. 15.. | Correct..... | .... | 24 | 67 | 31 | 16 | .... | 45 | 54 | .... | 29 | 35 | 86 | 42 | 41 |
| | P. ct. errors. | .... | 4.0 | 6.9 | 24.4 | 51.5 | .... | 6.3 | 8.4 | .... | 12.1 | 7.9 | 3.4 | 8.7 | 24.0 |
| Jan. 5.. | Correct..... | 35 | 23 | 71 | 38 | 16 | 39 | .... | .... | 9 | 26 | 29 | .... | 44 | 43 |
| | P. ct. errors. | 7.9 | 14.8 | 10.1 | 7.3 | 36.0 | 13.3 | .... | .... | 62.5 | 13.3 | 14.7 | .... | 0.0 | 8.5 |
| Normal av..... | Correct..... | 31.8 | 22.6 | 68.8 | 23.0 | 14.8 | 39.0 | 44.0 | 50.8 | 9.0 | 26.6 | 30.8 | 85.8 | 36.8 | 44.6 |
| | P. ct. errors. | 7.3 | 12.8 | 7.0 | 13.8 | 45.1 | 13.3 | 14.5 | 5.1 | 62.5 | 15.3 | 14.5 | 4.9 | 11.2 | 15.6 |
| Jan. 13.. | Correct..... | 33 | 18 | 68 | 31 | .... | 38 | 32 | .... | 14 | 24 | 36 | 79 | 41 | 48 |
| | P. ct. errors. | 10.8 | 28.0 | 6.9 | 18.4 | .... | 9.5 | 23.8 | .... | 44.0 | 14.3 | 5.3 | 10.2 | 10.9 | 11.1 |
| Jan. 19.. | Correct..... | 38 | 22 | 73 | 30 | .... | 36 | 42 | .... | 22 | 28 | 30 | 96 | 36 | 42 |
| | P. ct. errors. | 9.5 | 4.4 | 8.8 | 14.3 | .... | 16.3 | 14.3 | .... | 29.0 | 15.2 | 9.1 | 6.8 | 12.2 | 12.5 |
| Jan. 27.. | Correct..... | 32 | 25 | 72 | 46 | .... | 36 | 43 | .... | 21 | 24 | 33 | 103 | 44 | 49 |
| | P. ct. errors. | 20.0 | 7.4 | 6.5 | 9.8 | .... | 14.3 | 6.5 | .... | 30.0 | 7.7 | 10.8 | 1.9 | 4.3 | 12.5 |
| Low-diet av..... | Correct..... | 34.3 | 21.7 | 71.0 | 35.7 | .... | 36.7 | 39.0 | .... | 19.0 | 25.3 | 33.0 | 92.7 | 40.3 | 46.3 |
| | P. ct. errors. | 13.4 | 13.3 | 7.4 | 14.2 | .... | 13.4 | 14.9 | .... | 34.3 | 12.4 | 8.4 | 6.3 | 9.1 | 12.0 |

vidual's record from experiment to experiment, yet in general this is not such as to make it apparent that one individual influences predominantly the average for any one date. Five of the subjects whose records enter into the final averages for the squad, that is, *Can*, *Gul*, *Moy*, *Pec*, and *Vea*, have average low-diet errors of 10 per cent or above. Not one of these 5 subjects on any of the 9 dates which fell within the reduction period has a percentage of error less than 10 per cent. The largest is for *Pec* on October 13, viz, 40.7 per cent. This is somewhat compensated in the average by the fact that *Moy* on the same date had 20.1 per cent, which was a little below the average for him during the first part of the experiment. The errors for *Gul* were large, but during the greater part of the experiment they were quite consistent. Beginning with September 29 they are, in order, 25.0, 22.4, 24.5, 25.0, 18.3, 21.0, 23.8, 21.2, 12.3, and 12.7 per cent. The average score for Squad A during the whole of the reduction period, as shown at the bottom of the right-hand column in table 155, is 45.1 columns correct, with 15.5 per cent of errors.

In the case of Squad B the normal average performance shows that the individuals who made up this squad demonstrated a larger average variability than was found in Squad A. The scores for columns correctly added range from 85.8 and 68.8 for *Tho* and *How*, respectively, to 14.8 and 9.0 for *McM* and *Sch*. The data for the last two subjects are only fragmentary, as was also the case with *Spe* of Squad A. Nevertheless, there is somewhat more variability in Squad B, since no one in Squad A did so well as *Tho* and *How* of the former, and moreover, the scores of *Har* and *Ham* (22.0 and 23.0), both of Squad B, are slightly smaller than the smallest score with Squad A, *i. e.*, *Can*, 25.3.[1] The average normal performance for Squad B is 41.9 correct columns about 3 columns less than the low-diet average of Squad A.

In the matter of percentage of errors, with the exception of *Sch* and *McM*, whose data, particularly those of the former, have been mentioned as incomplete and do not enter into the average for Squad B, the values are in general in the same range as those found for Squad A. The final normal average of 11.8 per cent for Squad B is 3.7 per cent less than that found for Squad A. It is noteworthy that the two subjects of Squad B, who lead with the largest number of columns correctly added, are also in the lead in the smallest percentage of errors of any of the 10 subjects from whom the final squad average is drawn. In comparing Squad B's normal average with the average for the three reduced-diet dates, only minor fluctuations are noted. Seven of the 10 subjects show increase in the number of columns correctly added. Only 4 showed a reduction in the percentage of errors. The final average for this period shows an increase of 2 columns in the 10 minutes, *i. e.*, 43.9 compared to 41.9, and a decrease of 0.7 per cent in errors, 11.8 to 11.1 per cent.

[1] This comparison is among the 10 regular subjects of each squad.

The results are compared directly in figure 105. The performan of each squad is represented by three curves: (1) total number columns added in 10 minutes; (2) number of columns correctly add in 10 minutes; and (3) percentage of errors in the total number columns added. In the case of the total number of columns bo squads began at identically the same level. Squad A shows a rath smooth and gradual practice curve, with the exception of the poin at November 10 and February 2. On the latter date evidently speci effort was made. Squad B does not show so much improvemer The second session was slightly below the record of the first, but must be recalled that the time interval elapsing was 1 month. January 5 there is a distinct drop. This was apparently caused largest part by the absence of subject *Tho*, the champion adder of tl squad, who had been a bank clerk. *Tho*, because of transportatio

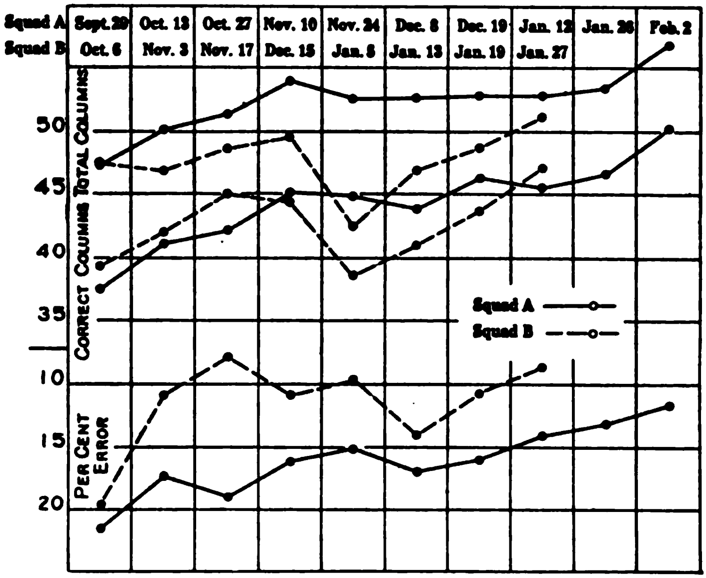



FIG. 105.—Average results in the 10-minute addition test.

difficulties in returning from the Christmas vacation, was unable reach the Laboratory on this evening until the group work had bee completed. Squad B also reached their highest point on the last dat January 27. The two preceding dates for this squad, January and 19, both of which were in the reduced-diet period, were not up the level that would have been expected on the basis of the performan for December 15 and previously. The whole squad was present January 13 and 19. One would therefore normally expect some i crease over previous experiments. The fact that there was none ma reasonably be charged to the low-diet conditions.

and 158, opposite the different dates and under the different subjects will be found the number of words correctly entered and also th

TABLE 157.—*Squad A—Memory span for 4-letter English words.*

| Date. | Words. | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pea. | Pec. | Spe. | Tom. | Ves. | Fre. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. Sept. 29.. | Correct.. | 7 | 5 | 6 | 4 | 6 | 6 | 4 | 10 | 7 | 7 | 10 | 8 | 6 | 6.7 |
| | Errors... | 0 | 1 | 3 | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 0 | 1 | 3 | 1. |
| Oct. 13.. | Correct.. | 11 | 6 | .... | 12 | 7 | 6 | 6 | 11 | 9 | 9 | 12 | 5 | 12 | 8. |
| | Errors... | 0 | 0 | .... | 1 | 0 | 3 | 1 | 0 | 2 | 0 | 1 | 3 | 2 | 1.1 |
| Oct. 27.. | Correct.. | 9 | 5 | 7 | 7 | 9 | 5 | 8 | 10 | 6 | 9 | 10 | 5 | .... | 7.4 |
| | Errors... | 1 | 0 | 2 | 3 | 0 | 3 | 2 | 2 | 1 | 1 | 1 | 5 | .... | 1. |
| Nov. 10.. | Correct.. | 11 | 7 | 6 | 8 | 7 | 5 | 11 | 6 | 5 | 10 | 11 | 9 | .... | 8.0 |
| | Errors... | 0 | 0 | 1 | 1 | 2 | 2 | 0 | ·3 | 2 | 2 | 1 | 0 | .... | 1.1 |
| Nov. 24.. | Correct.. | 10 | 7 | 4 | 9 | 8 | 4 | 10 | 6 | 7 | 10 | 9 | 7 | .... | 7.7 |
| | Errors... | 1 | 1 | 3 | 1 | 2 | 7 | 1 | 2 | 0 | 0 | 1 | 2 | .... | 1. |
| Dec. 8.. | Correct.. | 9 | 10 | 5 | 9 | 7 | 7 | 8 | 8 | 8 | 8 | 13 | 4 | .... | 8. |
| | Errors... | 0 | 2 | 3 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 3 | .... | 0. |
| Dec. 19.. | Correct.. | 10 | 7 | 7 | 10 | 6 | 7 | 10 | 9 | 8 | .... | 15 | 7 | .... | 8. |
| | Errors... | 1 | 1 | 1 | 2 | 1 | 2 | 0 | 2 | 2 | .... | 1 | 0 | .... | 1. |
| 1918. Jan. 12.. | Correct.. | 8 | 8 | 9 | 11 | 7 | 4 | 10 | 10 | 9 | .... | 12 | 7 | .... | 8. |
| | Errors... | 1 | 1 | 0 | 0 | 0 | 4 | 0 | 1 | 0 | .... | 1 | 0 | .... | 0. |
| Jan. 26.. | Correct.. | 10 | 10 | 6 | 9 | 9 | 7 | 11 | 9 | 8 | .... | 14 | 7 | .... | 9.4 |
| | Errors... | 0 | 0 | 1 | 1 | 1 | 4 | 1 | 0 | 1 | .... | 0 | 0 | .... | 0. |
| Feb. 2.. | Correct.. | 10 | 7 | 12 | 9 | 8 | 8 | 13 | 9 | 7 | .... | 13 | 7 | .... | 9.1 |
| | Errors... | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 2 | 0 | .... | 0 | 1 | .... | 0. |
| Low-diet av. | Correct.. | 9.8 | 7.5 | 7.0 | 9.3 | 7.6 | 5.9 | 9.7 | 8.7 | 7.4 | 9.2 | 12.1 | 6.4 | 12.0 | 8. |
| | Errors... | 0.4 | 0.6 | 1.4 | 1.2 | 0.9 | 3.0 | 0.9 | 1.3 | 0.9 | 0.6 | 0.8 | 1.6 | 2.5 | 1. |

TABLE 158.—*Squad B—Memory span for 4-letter English words.*

| Date. | Words. | Fis. | Har. | How. | Ham. | McM. | Kim. | Lon. | Mac. | Sch. | Liv. | Sne. | Tho. | Van. | Wil. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. Oct. 6 | Correct. | 7 | 5 | 5 | 7 | .... | .... | 13 | 10 | .... | 7 | 3 | 7 | 7 | 12 | 7. |
| | Errors.. | 1 | 2 | 3 | 1 | .... | .... | 1 | 0 | .... | 1 | 2 | 0 | 0 | 1 | 1. |
| Nov. 3 | Correct. | 7 | 8 | 10 | 10 | 6 | .... | 13 | 11 | .... | 6 | 7 | 6 | 10 | 10 | 8. |
| | Errors.. | 1 | 2 | 1 | 0 | 0 | .... | 0 | 0 | .... | 0 | 0 | 0 | 1 | 2 | 0. |
| Nov.17 | Correct. | 8 | 9 | 4 | 8 | 6 | .... | 10 | 12 | .... | 9 | 5 | 9 | 7 | 12 | 8. |
| | Errors.. | 1 | 0 | 3 | 0 | 1 | .... | 0 | 0 | .... | 0 | 1 | 0 | 1 | 4 | 1. |
| Dec. 15 | Correct. | .... | 6 | 6 | 7 | 6 | .... | 8 | 11 | .... | 8 | 9 | 9 | 7 | 9 | 7. |
| | Errors.. | .... | 1 | 1 | 1 | 1 | .... | 0 | 0 | .... | 0 | 0 | 0 | 3 | 2 | 0. |
| 1918. Jan. 5 | Correct. | 8 | 6 | 10 | 8 | 5 | 7 | .... | .... | 6 | 9 | 8 | .... | 10 | 13 | 9. |
| | Errors.. | 0 | 1 | 1 | 0 | 1 | 2 | .... | .... | 0 | 1 | 1 | .... | 0 | 3 | 0. |
| Normal av. | Correct. | 7.5 | 6.8 | 7.0 | 8.0 | 5.8 | 7 | 11.0 | 11.0 | 6 | 9.8 | 6.4 | 7.8 | 8.2 | 11.2 | 8. |
| | Errors.. | 0.8 | 1.2 | 1.8 | 0.4 | 0.8 | 2 | 0.3 | 0 | 0 | 0.4 | 0.8 | 0 | 1 | 2.4 | 0. |
| Jan. 13 | Correct. | 10 | 9 | 5 | 8 | .... | 9 | 12 | .... | 6 | 8 | 8 | 10 | 9 | 11 | 9. |
| | Errors.. | 1 | 0 | 1 | 0 | .... | 1 | 0 | .... | 4 | 1 | 1 | 0 | 0 | 2 | 0. |
| Jan. 19 | Correct. | 7 | 6 | 7 | 8 | .... | 7 | 14 | .... | 7 | 5 | 7 | 7 | 7 | 9 | 7. |
| | Errors.. | 0 | 0 | 1 | 0 | .... | 2 | 0 | .... | 3 | 1 | 0 | 0 | 2 | 2 | 0. |
| Jan. 27 | Correct. | 6 | 9 | 7 | 12 | .... | 9 | 12 | .... | 7 | 6 | 6 | 9 | 8 | 8 | 8. |
| | Errors.. | 2 | 1 | 1 | 0 | .... | 0 | 1 | .... | 4 | 0 | 1 | 0 | 0 | 4 | 1. |
| Low-diet av. | Correct. | 7.7 | 8.0 | 6.3 | 9.3 | .... | 8.3 | 12.7 | .... | 6.7 | 6.3 | 7.0 | 8.7 | 8.0 | 9.3 | 8. |
| | Errors.. | 1.0 | 0.3 | 1.0 | 0.0 | .... | 1.0 | 0.3 | .... | 3.7 | 0.7 | 0.7 | 0.0 | 0.7 | 2.7 | 0. |

the normal and 7.6 for the low diet. With the exception of *Lis*, F and *Fis*, all the 10 regular subjects show better scores for the low-period than during the normal sessions, that is, the improvement c tinued during the reduction in diet.

The relation between the scores of the two groups and the food duction period is brought out best in figure 106. Both curves sho tendency to improvement; Squad B is somewhat above A at beginning and in four of the other sessions. In the fourth session t

TABLE 159.—*Squad A—Memory score.*

TABLE 160.—*Squad B—Memory score.*

were at about the same level; in the seventh and eighth sessions Sq B dropped below. The fluctuations are rather large with both squ Squad B shows a falling off on November 17 and December 15, good results on January 5, *i. e.*, just after the vacation, a date shows poorly in several measurements. On January 13, their low-diet session, they have the best average of the whole experimen marked contrast to low-diet dates January 19 and January 27. Sq A demonstrates a large amount of variability in the early part of

investigation. The second session, as with B, showed great improvement over the first and the two squads came nearer to the same level. The average for the next three sessions is low. From December 8 to the end of the experiment, A showed consistent improvement, with relatively small changes from session to session.

The reduced diet can not be considered as favoring better scores than normal in the memory-span experiment. The decrease in the last two sessions with B and the poor scores in the third and fifth sessions for A seem in the direction of a low-diet effect. On the other hand, B, with no assigned reason, except that they did not receive so frequent practice as A, showed a marked decrease in the third and fourth sessions. Had they at these points kept up their

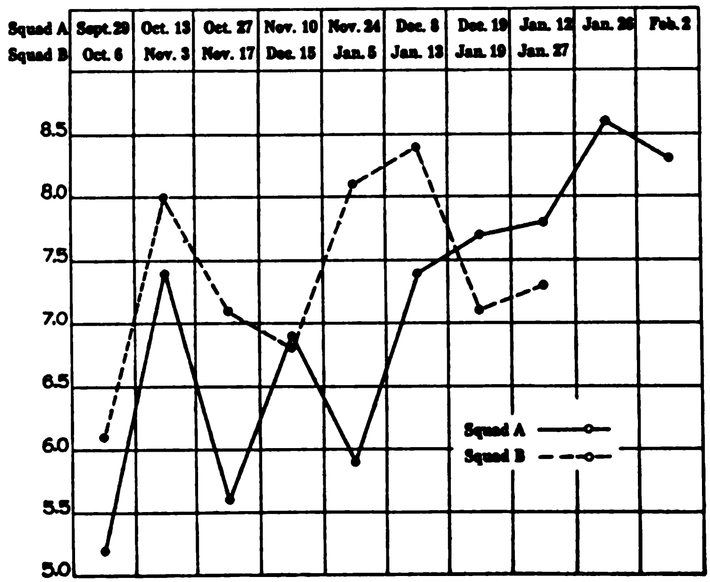



FIG. 106.—Average scores for memory span.

level of November 3 and January 5, Squad A would by contrast have made a poor record in the early part of the experiment, and B would have appeared to decline in the second and third experiments with food reduction. Our conclusions from the memory-span results can not be positive on account of the apparently large normal fluctuations in practice. It seems safest to believe that the reduced diet produced no certain change.

## THE INDIVIDUAL PSYCHOLOGICAL MEASUREMENTS.

### (6) STRENGTH OF GRIP.

It was the original plan in this investigation that strength and endurance tests should be given to the members of the squads from time to time in the gymnasium at Springfield. Circumstances over which

we had no control interfered and this part of the plan failed to materialize. Strength of grip was therefore made a part of the psychological program to help offset this deficiency. There are no records for the normal session of Squad A, *i. e.*, for September 29, with which the later ones may be compared. The results from tests made in the evening are given in tables 161 and 162 and entered separately for right and left hands. Five trials were made alternately with each hand, the figure given being the average of the five in kilograms. For each average there is a standard deviation and coefficient of variability.

In the evening records of Squad A (table 161), October 27 to February 2, inclusive, are during the low-diet period. As would be expected, the total individual averages are higher for the right hand than for the left.[1] The average for the right is 48.1 and for the left, 44.7, with a difference of about 3.5 kg. The individuals are very closely grouped. For the right hand the range is from 56.6 (*Gul*) to 41.6 kg. (*Pea*). The last-mentioned subject was left-handed. *Kon* shows almost equally good scores for both his hands. His record for the left hand of 54.8 kg. is the highest for the squad; the lowest average record with the left hand is 36.0 kg. for *Mon*. Five trials is not a large number from which to compute variability, but with the strength of grip test it is not desirable to take a large number of trials, since the element of fatigue soon enters as a prominent factor.

As explained in the section on method (page 150), the trials were separated by suitable intervals to minimize fatigue and to secure as nearly as possible an even performance. The general success of this can be judged definitely by the average coefficients of variability shown in the extreme right-hand column of the table with the other averages; these range from 3 to 6 per cent. Inspection of the table will show that the individual subjects were remarkably consistent in showing this small variability. The largest variability was with *Pea* on January 12 for the right hand—18.3 per cent. For this there is an explanation in that the subject had a sprained wrist which pained him when he used his full strength.

Squad B (table 162) showed averages higher than those of Squad A. The general averages for the four normal experiments are 55.1 kg. for the right hand and 51.6 kg. for the left as compared with 48.1 and 44.7 kg. for right and left, respectively, of Squad A. The individual subjects are here also very closely grouped about the general average.[2] Squad B in its low-diet averages for January 13, 19, and 27 has a total average for the right hand slightly above the normal (56.1 compared to 55.1 kg.) and for the left hand slightly below normal (50.9 compared

[1] In Squad A *Pea* and *Spe* were left-handed.

[2] *Kim*, *Lis*, *Sch*, and *Wil*, of Squad B, were left-handed; the first two are not included in the general averages.

TABLE 162.—*Squad B—Strength of grip at evening sessions.*
[Values in kilograms]

[1]R. and L. designate right and left hands; M., mean or average; S. D., standard deviation; and C., coefficient of variability.

TABLE 163.—*Squad A—Strength of grip at morning sessions.*

[Values given in kilograms.]

[1] R. and L. designate right and left hands; M., mean or average; S. D., standard deviatio and C., coefficient of variability.

TABLE 164.—*Squad B—Strength of grip at morning sessions.*

[Values in kilograms.]

| Date. | Hand.[1] | | Fla. | Har. | How. | Ham. | McM. | Kim. | Lon. | Mac. | Sch. | Liv. | Sne. | Tho. | Van. | Wil. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917 Nov. 4 | R. | M. | 56.3 | 51.5 | 61.1 | 50.6 | 44.4 | ..... | 55.7 | 56.6 | ..... | 46.5 | 59.4 | 51.9 | 58.0 | 52.5 | 54.4 |
| | | S.D. | 1.78 | 2.23 | 1.32 | 1.39 | 3.15 | ..... | 3.97 | 1.39 | ..... | 1.14 | 2.54 | 2.15 | 1.82 | 1.41 | 1.98 |
| | | C. | 3.2 | 4.3 | 2.2 | 2.7 | 7.1 | ..... | 7.1 | 2.5 | ..... | 2.5 | 4.3 | 4.1 | 3.1 | 2.7 | 3.6 |
| | L. | M. | 52.9 | 51.7 | 53.6 | 48.0 | 37.8 | ..... | 47.8 | 49.2 | ..... | 44.5 | 60.4 | 48.0 | 55.5 | 48.7 | 51.1 |
| | | S.D. | 1.88 | 2.48 | 1.20 | 1.58 | 2.11 | ..... | 3.72 | 1.21 | ..... | .95 | 1.39 | 1.64 | 1.00 | 1.47 | 1.73 |
| | | C. | 3.6 | 4.8 | 2.2 | 3.3 | 5.6 | ..... | 7.8 | 2.5 | ..... | 2.1 | 2.3 | 3.4 | 1.8 | 3.0 | 3.4 |
| Nov. 18 | R. | M. | 56.6 | 48.2 | 62.2 | 43.6 | 47.3 | ..... | 55.6 | 54.8 | ..... | 45.1 | 57.8 | 53.3 | 57.5 | 52.7 | 53.3 |
| | | S.D. | 1.28 | 1.29 | 4.01 | 1.83 | 3.03 | ..... | 2.01 | 1.57 | ..... | 1.20 | 1.63 | 3.26 | 1.70 | .93 | 1.91 |
| | | C. | 2.3 | 2.7 | 6.4 | 4.2 | 6.4 | ..... | 3.6 | 2.9 | ..... | 2.7 | 2.8 | 6.1 | 3.0 | 1.8 | 3.6 |
| | L. | M. | 53.4 | 50.2 | 53.2 | 43.2 | 40.3 | ..... | 47.7 | 50.2 | ..... | 44.8 | 56.8 | 46.6 | 55.2 | 51.1 | 50.2 |
| | | S.D. | 2.74 | 2.04 | 1.86 | 1.75 | .40 | ..... | 1.78 | 1.58 | ..... | .93 | 2.46 | 1.83 | 1.12 | 3.60 | 2.01 |
| | | C. | 5.1 | 4.1 | 3.5 | 4.1 | 1.0 | ..... | 3.7 | 3.1 | ..... | 2.1 | 4.3 | 3.9 | 2.0 | 7.0 | 4.0 |
| Dec. 16 | R. | M. | ..... | 46.9 | 60.1 | 42.9 | 47.2 | ..... | 55.6 | 55.0 | ..... | 44.4 | 59.5 | 49.5 | 55.1 | 49.5 | 51.9 |
| | | S.D. | ..... | 1.39 | 3.38 | 3.38 | 2.45 | ..... | 1.77 | 2.47 | ..... | 1.77 | 1.10 | 1.34 | .66 | 2.41 | 1.91 |
| | | C. | ..... | 3.0 | 5.6 | 7.9 | 5.2 | ..... | 3.2 | 4.5 | ..... | 4.0 | 1.8 | 2.7 | 1.2 | 4.9 | 3.7 |
| | L. | M. | ..... | 47.3 | 50.1 | 44.6 | 36.3 | ..... | 50.7 | 51.2 | ..... | 44.8 | 58.7 | 45.1 | 52.2 | 45.9 | 48.8 |
| | | S.D. | ..... | 1.26 | 1.32 | 3.38 | 2.23 | ..... | 5.08 | 2.77 | ..... | .98 | 1.36 | 1.27 | 1.03 | 1.96 | 1.96 |
| | | C. | ..... | 2.7 | 2.6 | 7.6 | 6.1 | ..... | 10.0 | 5.4 | ..... | 2.2 | 2.3 | 2.8 | 2.0 | 4.3 | 4.0 |
| 1918 Jan. 6 | R. | M. | 56.9 | 49.3 | 59.0 | 48.0 | 49.7 | 44.5 | ..... | ..... | 57.5 | 45.3 | 54.2 | 49.1 | 57.4 | 46.9 | 51.8 |
| | | S.D. | .99 | 1.33 | 5.24 | 1.82 | .87 | 1.90 | ..... | ..... | 1.18 | .93 | 1.91 | 2.58 | 1.36 | 1.83 | 2.00 |
| | | C. | 1.7 | 2.7 | 8.9 | 3.8 | 1.8 | 4.3 | ..... | ..... | 2.1 | 2.0 | 3.5 | 5.3 | 2.4 | 3.9 | 3.9 |
| | L. | M. | 54.6 | 51.4 | 50.0 | 45.1 | 38.3 | 44.5 | ..... | ..... | 54.0 | 44.5 | 53.7 | 45.0 | 54.5 | 45.8 | 49.4 |
| | | S.D. | 1.39 | 1.98 | 2.51 | 1.20 | 1.60 | 3.74 | ..... | ..... | 2.12 | .63 | 2.25 | 1.05 | .89 | 2.42 | 1.59 |
| | | C. | 2.5 | 3.9 | 5.0 | 2.7 | 4.2 | 8.4 | ..... | ..... | 3.9 | 1.4 | 4.2 | 2.3 | 1.6 | 5.3 | 3.2 |
| Normal av... | R. | M. | 56.6 | 49.0 | 60.6 | 46.3 | 47.2 | 44.5 | 55.6 | 55.5 | 57.5 | 45.3 | 57.7 | 51.0 | 57.0 | 50.4 | 52.9 |
| | | M. | 53.6 | 50.2 | 51.8 | 45.2 | 38.2 | 44.5 | 48.7 | 50.2 | 54.0 | 44.7 | 57.4 | 46.2 | 54.4 | 47.9 | 49.9 |
| Jan. 14 | R. | M. | 60.0 | 51.0 | 54.0 | 45.7 | ..... | 41.0 | 55.0 | ..... | 54.1 | 46.6 | 57.7 | 52.1 | 54.7 | 48.8 | 52.6 |
| | | S.D. | 2.10 | .95 | .57 | 1.66 | ..... | 2.26 | 1.52 | ..... | .66 | 1.07 | 1.25 | 2.15 | 1.69 | 1.03 | 1.40 |
| | | C. | 3.5 | 1.9 | 1.1 | 3.6 | ..... | 5.5 | 2.8 | ..... | 1.2 | 2.3 | 2.2 | 4.1 | 3.1 | 2.1 | 2.7 |
| | L. | M. | 54.0 | 54.1 | 34.3 | 40.8 | ..... | 44.0 | 47.4 | ..... | 52.7 | 42.6 | 52.6 | 46.0 | 51.8 | 46.2 | 47.0 |
| | | S.D. | 1.52 | 1.77 | 1.89 | 3.11 | ..... | 2.90 | 2.71 | ..... | .97 | 1.70 | 1.39 | .84 | 1.63 | 2.80 | 1.94 |
| | | C. | 2.8 | 3.3 | 5.5 | 7.6 | ..... | 6.6 | 5.7 | ..... | 1.8 | 4.0 | 2.6 | 1.8 | 3.1 | 6.1 | 4.1 |
| Jan. 20 | R. | M. | 60.3 | 50.7 | 55.8 | 50.8 | ..... | 45.1 | 50.4 | ..... | 51.5 | 46.4 | 56.5 | 51.9 | 55.5 | 47.7 | 52.6 |
| | | S.D. | .40 | 2.66 | 1.44 | 2.29 | ..... | 1.74 | 2.27 | ..... | 1.10 | 1.02 | 1.89 | 2.11 | 1.18 | 2.54 | 1.78 |
| | | C. | 6.6 | 5.2 | 2.6 | 4.5 | ..... | 3.9 | 4.5 | ..... | 2.1 | 2.2 | 3.3 | 4.1 | 2.1 | 5.3 | 3.4 |
| | L. | M. | 56.4 | 52.3 | 36.1 | 46.2 | ..... | 46.1 | 43.3 | ..... | 47.8 | 42.0 | 50.6 | 47.4 | 51.0 | 47.0 | 47.2 |
| | | S.D. | 2.03 | 3.09 | 1.50 | 1.17 | ..... | 3.18 | 2.48 | ..... | .51 | 1.10 | 2.42 | .58 | 1.27 | 4.00 | 1.96 |
| | | C. | 3.6 | 5.9 | 4.2 | 2.5 | ..... | 6.9 | 5.7 | ..... | 1.1 | 2.6 | 4.8 | 1.2 | 2.5 | 8.5 | 4.2 |
| Jan. 28 | R. | M. | 59.0 | 52.1 | 59.2 | 50.8 | ..... | 49.2 | 53.5 | ..... | 53.4 | 46.6 | 55.7 | 50.7 | 55.2 | 47.3 | 53.0 |
| | | S.D. | .89 | 3.20 | .93 | 2.62 | ..... | 2.42 | 2.10 | ..... | 1.50 | .86 | 1.69 | 1.17 | .93 | .81 | 1.52 |
| | | C. | 1.5 | 6.1 | 1.6 | 5.2 | ..... | 4.9 | 3.9 | ..... | 2.8 | 1.8 | 3.0 | 2.3 | 1.7 | 1.7 | 2.9 |
| | L. | M. | 56.5 | 50.8 | 42.5 | 45.3 | ..... | 49.8 | 48.4 | ..... | 51.2 | 42.1 | 53.7 | 44.1 | 52.4 | 48.2 | 48.4 |
| | | S.D. | 2.59 | 1.12 | 1.97 | 2.48 | ..... | 2.36 | 1.02 | ..... | .68 | .73 | 1.50 | 1.39 | .86 | 1.63 | 1.53 |
| | | C. | 4.6 | 2.2 | 4.6 | 5.5 | ..... | 4.7 | 2.1 | ..... | 1.3 | 1.7 | 2.8 | 3.2 | 1.6 | 3.4 | 3.2 |
| Low-diet av... | R. | M. | 59.8 | 51.3 | 56.3 | 49.1 | ..... | 45.1 | 53.0 | ..... | 53.0 | 46.5 | 56.6 | 51.6 | 55.1 | 47.9 | 52.7 |
| | L. | M. | 55.6 | 52.4 | 37.6 | 44.1 | ..... | 46.6 | 46.4 | ..... | 50.6 | 42.2 | 52.3 | 45.8 | 51.7 | 47.1 | 47.5 |

[1] R. and L. designate right and left hands; M., mean or average; S. D., standard deviation; and C., coefficient of variability.

The difference in level between the curves of the two squads i significant but of unknown value, as records were not obtainable fo the normal condition of Squad A before they began the reduced diet As it was considered that the members of Squad A would have returne to somewhat near their normal condition by May 21, it was arrange that the 6 members of Squad A who still remained in college shoul take a strength of grip test with the same instrument and under th usual instructions and supervision. The data which were gathere are included in table 161 for the evening record. The data for eac subject may be conveniently compared with the low-diet averag immediately above. For May 21 *Bro* shows a right-hand average o 51.0 kg. as compared to a low-diet average of 51.6 kg., and a left-han average of 45.8 compared to a low-diet average of 45.3 kg.; that is, wit this subject there is practically no change. With the other 5 subjects however, the condition is very different: *Can* shows for the right hand rise from 54.0 to 57.5 and for the left hand from 47.6 to 53.9; *Moy'* record for the right hand changes from 44.5 to 52.6 and for the lef hand from 42.1 to 52.4. *Pea* said his wrist was still weak and ineffi cient; his records show, however, an increase from 41.6 to 50.8 for the right hand and from 50.3 to 55.7 for the left hand. *Spe* gave a right-hand score which changed from 46.6 to 47.5, and for the left hand 46.5 to 48.1, and lastly, *Vea* shows right hand 45.4 to 51.9 and left hand a record of 41.1 as compared with his later average of 46.1. The averages for these 6 subjects of Squad A during the low-diet period were right hand, 47.3, left hand, 45.5, a compared with the scores for May 21 with right hand 51.9 and left hand 50.3. The variability figures for these records of May 21 are, on the average, the smallest found at any time for Squad A, thus indi cating great consistency in the records of that date. It seems very

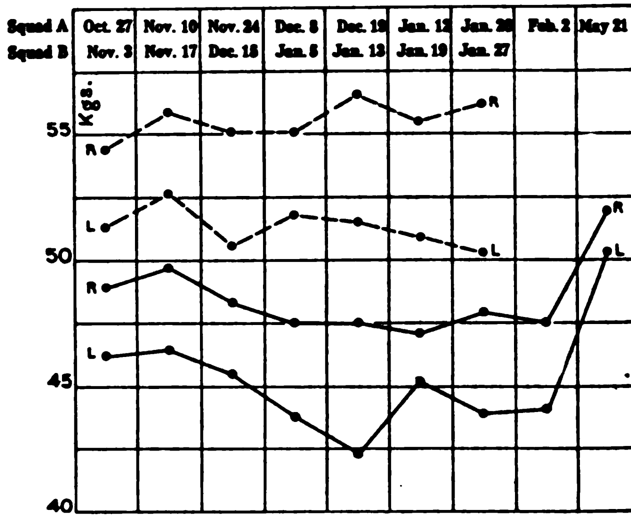



FIG. 107.—Averages for strength of grip at evening sessions an with six members of Squad A on one date following the low diet experiment.

*R* and *L* designate right and left hands. Solid line curves represen Squad A, and broken lines Squad B.

evident that with the uncontrolled eating there was a change, at least with 5 out of 6 men, and the strength of grip had increased roughly 4.5 kg. with each hand. This is nearly enough to account for the difference in level of the two squads shown in figure 107. If a comparison is made between the low-diet averages for the 6 subjects under special consideration and the low-diet average for the whole group, as shown in table 161 (48.1 and 44.7 for the right and left hands, respectively), it will be noted that these 6 men average very nearly the same as the whole group. It is therefore permissible to plot points on figure 107, showing the level of the performance of May 21. This has been done at the right side of the figure. These two points are seen to be definitely above any other performance of Squad A and to be in the range of Squad B, although in the case of the right hand not so high.[1]

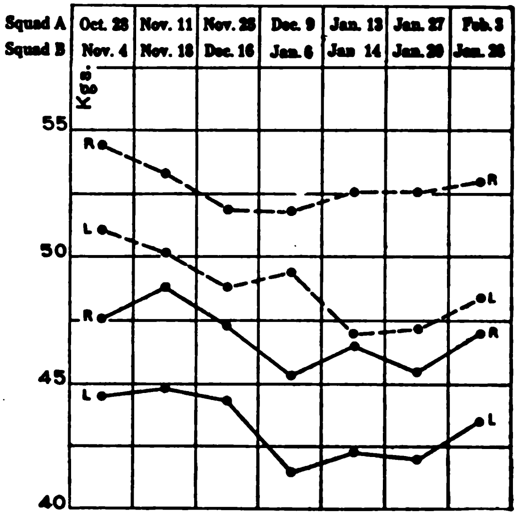



FIG. 108.—Averages for strength of grip at morning sessions.

*R* and *L* designate values for right and left hands. Solid line curves represent Squad A, and broken lines, Squad B.

The curves for the morning records (fig. 108) show the interesting result that both squads are a little nearer the same level, although Squad B is still at a higher level than Squad A. The gradual decline shown by the records of Squad B from the first performance of November 4 is striking. Squad B made their best morning record on the first morning experiment, November 4. It is difficult to assign a reason for this gradual decline in succeeding sessions. The conditions in the morning were somewhat different from those in the evening, since each subject was tested by himself in room B; consequently, when the subject was making his record he did not have the stimulating presence of someone sitting at the side watching. It is possible that this factor may be of considerable importance here, as it is frequently noted in the literature on strength of grip and ergographic experiments. Squad B with the left hand shows a marked drop on the three dates, January 14, 20, and 28, which were during the low diet. There was, during the same period, a very slight rise in the record with the right

[1] Of this group of 6 men tested on May 21, *Pea* and *Spe* were left-handed.

hand. Squad A made their be t record at the second morning session, November 11. Following this, the irregularity is not marked, and all of the averages are definitely lower. There was somewhat of a rise on the morning of February 3, probably assignable to the more or less stimulating conditions at the close of the experiment, as the strength of grip followed the walking and was the last test before the subject broke training.

The variability in the strength of grip is shown in figures 109 and 110 for the evening and morning performance, respectively. Separate curves are given for the right and left hands. There appear no conspicuous differences between the two squads in relation to this factor. The variability value is always small, never larger than 6 per cent, even though there is considerable relative fluctuation in its size. The curves cross and recross, but in general maintain the same level. In the case of the evening records (fig. 109), Squad A has relatively a large variabilitv with the left hand on October 27 (6 per cent). Following this, the variability usually ranges between 3 and 4 per cent. As the experiment continues, it tends to decrease. This irregular decrease in the variability is found with both squads and in both the evening and morning records, but is more prominent in the former. The small variability found on May 21 (see fig. 109) is remarkable and in striking contrast to that for October 27, the firs evening session, and for October 28, the first morning session (see fig. 110), even though 2½ months intervened between February 2 and May 21.

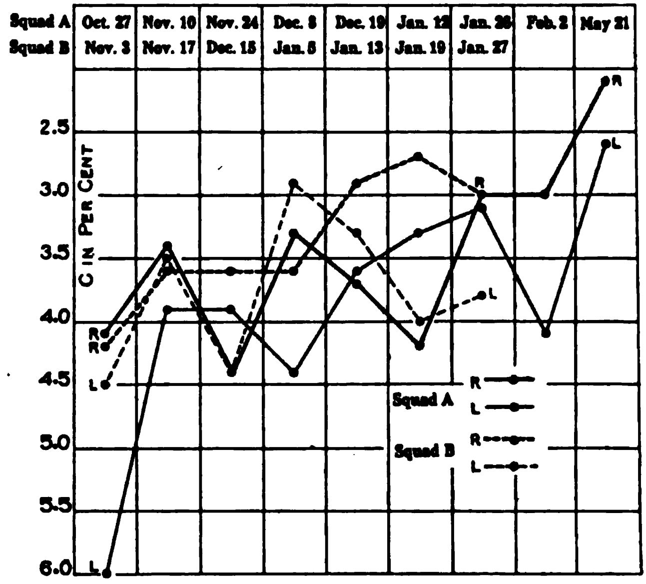



FIG. 109.—Variability in the average strength of grip at evening sessions.

*R* and *L* designate values for right and left hands.

In a strength test there are at least two conditions which favor increased variability: (1) any changing interest or fluctuating attention in connection with the test; (2) the extremeness of the muscular

efforts with the result of quick development of fatigue or conditions which produce pain. Squad A made better averages in their first two sessions than in any of the subsequent periods, and the variability tends to be largest; there would seem to be some connection between these two factors. The changes in variability with Squad B are not so marked; they were about the same level all the time, with some decrease in the case of evening work particularly.

In summarizing the effect of the reduced diet on the strength of grip, we have to consider these facts: (1) There are two squads of 10 men each with no apparent reason for believing that the average grip strength of one squad should be much greater than the other under normal conditions. With Squad A on reduced rations, we find a definite difference between the two groups of men. (2) Records taken with 6 of the members of Squad A after the reduced-diet period and at a time when it might be considered that the men had returned to approximately normal conditions, show, on the average, a strength of grip about 4.5 kg. greater than that demonstrated during the low-diet period. (3) There was a gradual reduction in the strength of grip with Squad A from the beginning until the last of the experiment. (4) In the 3 weeks' diet period with Squad B there was some reduction below the previous performance. (5) In all the records, the coefficient of variability for individual series of five trials remains quite constant at about 4 per cent, thus indicating uniformity of effort in the test. It would therefore seem that the strength of grip was definitely lowered by the reduced diet régime. In the absence of normal measurements for Squad A previous to the period of diet and for half of the men subsequent to the experiment, it is impossible to say how large the reduction may be. It is not unreasonable to believe that it averaged about 4 kg. in 50, which amounted to approximately an 8 per cent reduction in strength as exhibited in this test.

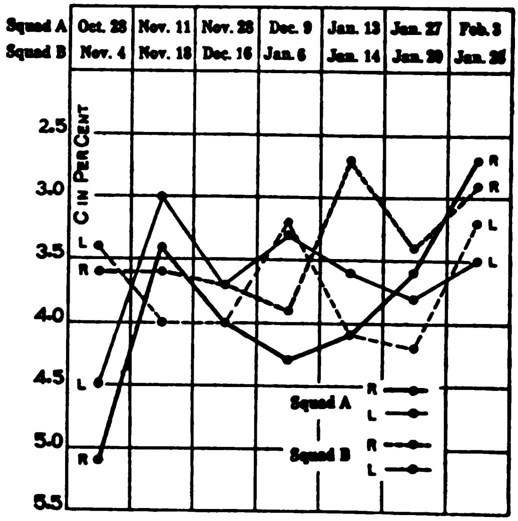



FIG. 110.—Variability in the average strength of grip at morning sessions.

*R* and *L* designate values for right and left hands.

(8) LATENCY, AMPLITUDE, AND REFRACTORY PERIOD OF PATELLAR REFLE

Of all the human reflexes that may be elicited by appropriate stimu that of the patellar lends itself most conveniently to measuremen No doubt the method of recording the latency, amplitude, a refractory period of this reflex from the thickening of the quadrice muscle is, all things considered, the most satisfactory techniqu The term "reflex arc" is associated with such ideas as simplicity a invariability, in short, constancy of response. Physiologists, howev who have worked with human reflexes, and specifically with t patellar reflex, have soon discovered that this is not a constant in time relations or in its amplitude. Our data for the 63 young men the normal series of 1917, with whom the patellar reflex was measur with identical apparatus and procedure as in the low-diet researc may be examined in connection with this matter of the variability this reflex. In the first place, it is noteworthy that of the 63 men the were 15 from whom the reflex could not be obtained in measurab amplitude. Every effort was made to adjust the apparatus to exact the proper height on the tendon, to see that the leg of the subject w in a comfortable position, and that the subject was relaxed, as in cated by the condition of his leg muscles. Our failure was, therefo not because of lack of time or care in trying to secure the reflex. was because under our conditions for stimulation and on that da the reflex could not be produced. In several of these cases, when tr was made with the legs crossed and by the usual clinical method, the was some reflex, but of course this was not measurable as to laten or amplitude under such conditions.

The 48 men from whom measurable series of reflexes were obtain gave an average latency (average of all individual averages) of 32 The standard deviation for this series of 48 patellar reflex latenci was 6.6 $\sigma$, the coefficient of variability, therefore, being 21 per ce We may anticipate our results slightly here and point out that t coefficient of variability is larger than a similar coefficient for neu muscular processes, such as reactions and muscle coordinations, whi are usually considered much more complex than the patellar refle The average amplitude of the primary reflex for the 48 indiv dua was 15 mm. This is a magnification of 6 times the extent of actu muscle-thickening. With different subjects the average amplitu

[1]Measurement No. 7 (changes in pulse-rate occasioned by short periods of exertion) is discus with the other pulse data; see p. 415.

[2]Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 36.

[3]This average is for the reflexes of the first stimulus. On page 155 it is explained that t pendulum hammers were used to stimulate for the reflex. The second hammer was to fall agai the knee at a variable interval from the stimulus of the first. When this interval was sho there was no response, that is, the reflex was refractory. When it was fairly long there wa response, in some cases almost as large as the primary reflex. These secondary reflexes, howev which followed shortly upon the primary, are not counted in the averages. $\sigma$ is used as an abb viation for 0.001 second.

very small or absent with *Pec* and *Bro*, and was exceedingly irreg with *Tom*. *Fre* served but a short time, and *Spe* was ill from cember 19 to the end of the experiment. *Gar* showed a peculiar ela vibration of the muscle which greatly complicated the curves and m many of them illegible and other readings untrustworthy. The av ages in the extreme right-hand column of table 165 are from th subjects, *Can*, *Kon*, *Gul*, *Mon*, *Moy*, and *Vea*, with whom reasona complete records were obtained. Even with these there were a num of breaks. The one with *Kon* on October 13, was due to his com into Squad A late, as explained on page 557. Opposite each d and in the vertical column, the average values for latency, amplitu and separation of stimuli are recorded for each subject. The aver for the 6 men for September 29 shows 34 σ for latency, 22 mm.

TABLE 165.—*Squad A—Patellar reflex latency, amplitude, and refractory period.*[a]

[a]L., A., and S. designate latency in 0.001 ″(σ), amplitude, in mm., and separation in 0.01″. the body of the table the index figures refer to the following notes:

[1]No reflexes.
[2]No failures with short S.; all very small.
[3]Summation evident.
[4]Second contact out of order.
[5]Illegible.
[6]Irregular voluntary contraction following mary reflex.
[7]Leg feels tighter against apparatus.

amplitude, and 0.17 second for separation, *i. e.*, refractory period. These values are in the same range as those mentioned for the series of 1917, which were 32 σ, 15 mm., and 0.25 second. The individual subjects do not show extraordinary variation among themselves or with any individual from date to date.

In the case of Squad B there were only 4 men, *Fis*, *Har*, *Sne*, and *Tho*, with whom the patellar reflex was usually present in measurable amplitude and whose records are reasonably complete for the series of experiments. On the first date, October 6, these four show averages of 37 σ for latency, 23 mm. for amplitude, and 0.18 second for refractory period separation. All of the values, considering the process under discussion, are in reasonable agreement with the previous values which have been mentioned as possible standards.

TABLE 166.—*Squad B—Patellar reflex latency, amplitude, and refractory period.**

*L., A., and S. designate latency in 0.001 second (σ), amplitude in millimeters, and separation in 0.01 second. In the body of the table the index figures refer to the following notes:
[1]No reflexes.
[2]No failures with short S.; all very small.
[3]Summation evident.
[4]Second contact out of order.

It will be more convenient to compare the results with the two squads under conditions of normal eating and reduced diet from the plotted values in figure 111. The solid lines are for Squad A, the broken lines for Squad B. The two curves at the top of the figure give the latency. Beginning with 34 σ on September 29, Squad A in their second experi-

ment showed a reflex time lengthened to 42 $\sigma$. The latency was also longer than normal in the next three experiments, October 27, November 10, and November 24. On December 8 it was the same value as the normal, but on the succeeding four dates it was longer, conspicuously so on January 26. Squad B began with a longer latency than A. The first two experiments separated by 1 month show the same latency, 37 $\sigma$. At the next date this was lengthened to 44 $\sigma$, a rather conspicuous and unaccountable change.[1] On De-

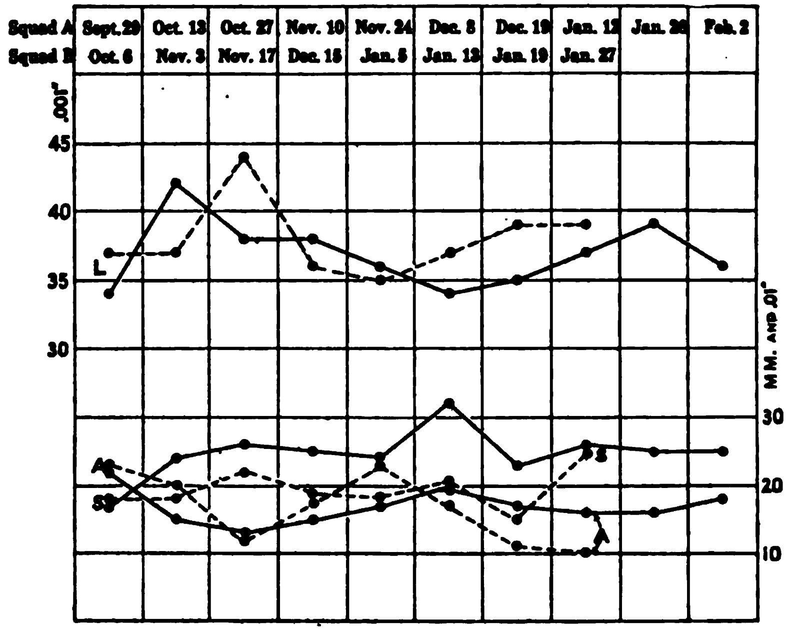



FIG. 111.—Patellar reflex averages.

*L*, latency; *A*, amplitude, and *S*, refractory period separation. The scale at the left is for 0.001 second, that at the right is for millimeters in the case of *A* and for 0.01 second for *S*. Solid lines represent Squad A, and broken lines Squad B.

cember 15 and January 5 the latency was slightly shorter than on the previous days, October 6 and November 3. On January 13 it was at the initial level, that is, 37 $\sigma$. This was the first low-diet date. On the next two, January 19 and 27, the latency was longer than at any other point save November 17.

The curves for the amplitude of the reflexes tend in each case to be the complement of those for the latency. When the latency is long the amplitude is small, and *vice versa*. Squad A shows a decrease in the amplitude for October 13, 27, and November 10. This accompanied the increase in latency. Squad B likewise shows a decrease in amplitude on November 17 with their associated latency of 44 $\sigma$, but

[1] See discussion of November 18 in relation to speed of eye movements, page 621.

63 men in the series of 1917 show a general average of 244 σ, wit standard deviation of 46 σ; the individual averages range from to 415 σ. Besides the individual with the average of 415 σ, which n not be a typical eye reaction, there were 3 other men in the nor series of 1917 who had reaction times of 340 σ or longer, that is: 3 347, and 346 σ. Not one of the 63 subjects had previously served this measurement. It was deemed of interest to take account of shortest reactions which the individual subjects made,[1] as th minimum reaction times would appear to be less complicated fluctuations in attention than is the general average of a series reactions. The five shortest reactions made by each of the 63 men w therefore averaged. The general average of the 63 minimum avera shows 193 σ, with a standard deviation of 44 σ.

With but few exceptions, all of the eye reactions for the men of normal series of 1917 were included in the averages. An inspection the records of prolonged series of reactions taken with other individu and also in the present low-diet research reveals the fact that quently the first reaction made by a subject is unusually long apparently quite out of uniformity with the subsequent reactio On the other hand, these long initial reactions were not invaria found. While on general grounds it is not permissible to omit cert data on the supposition that it fails to fit in with one's standard normality, yet it is possible to adopt some arbitrary method of de ing with such difficulties. The following rules were employed in av aging the eye-reaction data for this research:

(1) If, in the first set of eye reactions taken with a subject, that the first time this measurement was made on him, the first two re tions were abnormally long (350 σ or longer), they were *both* omit from the average and considered as preliminary practice.

(2) Two plates were taken on the subject at each sitting or exp mental evening. At each subsequent evening after the first, if first reaction on either plate was abnormally long, it was also omit from the average and considered as preliminary practice for evening.

(3) Abnormally long reactions which occurred at any other pla in the records than those specified were invariably included in averages.

The individual eye-reaction time averages with standard deviati and coefficients of variability are given in tables 167 and 168 for Squ A and B, respectively. Squad A shows 231 and Squad B 237 σ as av ages for the first reactions taken from the two groups of men with t technique. The average standard deviation in each case amou to 20 per cent of the reaction time, the two standard deviations bei

[1]Diefendorf and Dodge, Brain, 1908, 31, p. 472.

47.9 and 50.6 σ respectively. These values correspond very nearly with the 244 σ, and coefficient of variability of 19 per cent for the normal series of 1917. The averages for Squads A and B are about 10 σ less, due, no doubt, to our method of dealing with the preliminary long reactions just mentioned. The average reaction times for Squads A and B for other dates than October 28 and November 4, with the exception of the fragmentary data for November 11 (Squad A), always show smaller values than on the original first date. Such a practice effect is normal for untrained subjects in this measurement. It was found by Dodge and Benedict in the eye reaction data in their alcohol investigation.[1] It is clearly evident in an unpublished series of eye reactions secured with trained subjects in this Laboratory; it also shows definitely in this low-diet research.

TABLE 167.—*Squad A—The eye-reaction time and its variability.*
[M. in σ, S. D. in σ, and C. in per cent.]

| Date. | Reaction. | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pea. | Pec. | Spe. | Tom. | Vea. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917 Oct. 28. | M. | 331 | 181 | 244 | 253 | 185 | 255 | 225 | 237 | 223 | 277 | 195 | 225 | 231 |
| | S.D. | 61 | 26 | 82 | 72 | 28 | 57 | 65 | 52 | 47 | 68 | 32 | 39 | 47.9 |
| | C. | 18.4 | 14.4 | 33.6 | 28.4 | 15.1 | 22.3 | 28.9 | 21.9 | 21.1 | 24.5 | 16.4 | 17.3 | 20.4 |
| Nov. 11. | M. | (2) | [1]235 | 234 | [1]240 | (2) | (2) | 241 | 261 | (2) | 262 | (2) | 192 | 233 |
| | S.D. | ..... | 62 | 41 | 26 | ..... | ..... | 59 | 69 | ..... | 49 | ..... | 20 | 47.2 |
| | C. | ..... | 26.4 | 17.5 | 10.8 | ..... | ..... | 24.5 | 26.4 | ..... | 18.7 | ..... | 10.9 | 19.8 |
| Nov. 25. | M. | 223 | 175 | 223 | 234 | 311 | 240 | 205 | 215 | 240 | 247 | 227 | 209 | 218 |
| | S.D. | 65 | 26 | 77 | 65 | 52 | 59 | 37 | 41 | 83 | 50 | 84 | 44 | 55.6 |
| | C. | 29.1 | 14.9 | 34.5 | 27.8 | 24.6 | 24.6 | 18.0 | 19.0 | 34.6 | 20.2 | 37.0 | 21.0 | 25.1 |
| Dec. 9. | M. | 207 | 170 | 234 | 217 | 170 | 200 | 211 | 219 | 200 | 276 | 210 | 189 | 199 |
| | S.D. | 65 | 30 | 94 | 59 | 26 | 32 | 40 | 48 | 33 | 75 | 66 | 25 | 42.4 |
| | C. | 31.4 | 17.6 | 40.2 | 37.2 | 15.3 | 16.0 | 19.0 | 21.9 | 16.5 | 27.2 | 31.4 | 13.2 | 22.0 |
| 1918 Jan. 13. | M. | 243 | 178 | 211 | 210 | 184 | 226 | 213 | 227 | 226 | ..... | 201 | 188 | 210 |
| | S.D. | 56 | 32 | 70 | 41 | 25 | 36 | 33 | 49 | 46 | ..... | 36 | 22 | 37.6 |
| | C. | 23.0 | 18.0 | 33.2 | 19.5 | 13.6 | 15.9 | 15.5 | 21.6 | 20.3 | ..... | 17.9 | 11.7 | 17.7 |
| Jan. 27. | M. | 242 | (2) | 156 | 203 | 180 | 199 | 209 | 259 | 206 | ..... | 196 | 180 | 208 |
| | S.D. | 53 | ..... | 22 | 33 | 39 | 25 | 33 | 84 | 32 | ..... | 28 | 17 | 38.2 |
| | C. | 21.9 | ..... | 14.1 | 16.3 | 21.7 | 12.6 | 15.8 | 32.4 | 15.5 | ..... | 14.3 | 9.5 | 17.8 |
| Low-diet av.... | M. | 249 | 188 | 217 | 226 | 186 | 224 | 217 | 236 | 219 | 266 | 206 | 197 | 217 |
| | S.D. | 60 | 35 | 64 | 49 | 34 | 42 | 45 | 57 | 48 | 61 | 49 | 28 | 44.8 |
| | C. | 24.8 | 18.3 | 28.9 | 23.3 | 18.1 | 18.3 | 20.3 | 23.9 | 21.6 | 22.7 | 23.4 | 13.9 | 20.5 |

[1]Very few data secured, but all are averaged in. [2]Action of shutter defective.

For the individual men of Squad A, the average reaction times for the whole series, from October 28 to January 27, range from 186 σ (*Gul*) to 249 σ (*Bro*). *Spe* shows an average, 266 σ, which is still higher. He did not, however, have so much opportunity for practice. All his reaction records show abnormally long times. The average variability for the individual subjects ranges from 18 to 29 per cent. The average reaction time for the whole experiment for the ten men

[1]Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 89.

is 217 $\sigma$, with an average individual variability of 20.5 per cent. With Squad B the general average for the 3 normal experiments is 224 $\sigma$, with like variability of 20.5 per cent. The average for the 2 low-diet experiments is 206 $\sigma$, with a variability of 19 per cent. The averages and variabilities for the individual subjects are not particularly noteworthy.

There were no normal eye-reaction experiments for Squad A. The total number of these measurements was further reduced by the treadmill experiments on January 6 and 28 with Squad B, and on February 3 with Squad A, and the standard electrocardiograms on December 20 with Squad A, as on all four dates the morning psychological program had to be omitted.[1]

TABLE 168.—*Squad B—The eye-reaction time and its variability.*
[M. in $\sigma$, S. D. in $\sigma$, and C. in per cent.]

| Date. | Reaction. | Fis. | Har. | How. | Ham. | McM. | Kim. | Lon. | Mac. | Sch. | Liv. | Sne. | Tho. | Van. | Wil. | A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917 Nov. 4.. | M. | 207 | 269 | 298 | 221 | 239 | ..... | 268 | 252 | ..... | 248 | 223 | 225 | 202 | 204 | 237 |
| | S.D. | 44 | 48 | 62 | 39 | 48 | ..... | 91 | 50 | ..... | 60 | 45 | 28 | 52 | 37 | 5 |
| | C. | 21.3 | 17.8 | 20.8 | 17.6 | 20.1 | ..... | 33.9 | 19.8 | ..... | 24.2 | 20.2 | 12.4 | 25.7 | 18.1 | 2 |
| Nov. 18.. | M. | 207 | ..... | 285 | 175 | 202 | ..... | 230 | 200 | ..... | 246 | 212 | 202 | 209 | 179 | 21 |
| | S.D. | 30 | ..... | 59 | 33 | 42 | ..... | 44 | 35 | ..... | 45 | 40 | 22 | 54 | 36 | 4 |
| | C. | 14.5 | ..... | 20.7 | 18.9 | 20.8 | ..... | 19.1 | 17.5 | ..... | 18.3 | 18.9 | 10.9 | 25.8 | 20.1 | 1 |
| Dec. 16.. | M. | ..... | 252 | 234 | 217 | 197 | ..... | 268 | 175 | ..... | 237 | 191 | 195 | 203 | 190 | 22 |
| | S.D. | ..... | 54 | 53 | 48 | 45 | ..... | 91 | 40 | ..... | 45 | 32 | 28 | 40 | 48 | 4 |
| | C. | ..... | 21.4 | 22.6 | 22.1 | 22.8 | ..... | 34.0 | 22.9 | ..... | 19.0 | 16.7 | 14.4 | 19.7 | 25.3 | 2 |
| Normal av.. | M. | 207 | 261 | 272 | 204 | 213 | ..... | 255 | 209 | ..... | 244 | 209 | 207 | 205 | 191 | 22 |
| | S.D. | 37 | 51 | 58 | 40 | 45 | ..... | 75 | 42 | ..... | 50 | 39 | 26 | 49 | 40 | 4 |
| | C. | 17.9 | 19.6 | 21.4 | 19.5 | 21.2 | ..... | 29.0 | 20.1 | ..... | 20.5 | 18.6 | 12.6 | 23.7 | 21.2 | 2 |
| 1918 Jan. 14.. | M. | 199 | 236 | 226 | 206 | ..... | 240 | 238 | ..... | 207 | 223 | 202 | 185 | 210 | 183 | 21 |
| | S.D. | 37 | 56 | 37 | 47 | ..... | 69 | 52 | ..... | 42 | 44 | 42 | 28 | 48 | 33 | 4 |
| | C. | 18.6 | 23.7 | 16.4 | 22.8 | ..... | 28.7 | 21.8 | ..... | 20.3 | 19.7 | 20.8 | 15.1 | 22.9 | 18.0 | 2 |
| Jan. 20.. | M. | 204 | 218 | 200 | 195 | ..... | 221 | 243 | ..... | 194 | 219 | 180 | 169 | 194 | 175 | 20 |
| | S.D. | 36 | 37 | 28 | 22 | ..... | 70 | 90 | ..... | 26 | 45 | 41 | 20 | 28 | 22 | 3 |
| | C. | 17.6 | 17.0 | 14.0 | 11.3 | ..... | 31.7 | 37.0 | ..... | 13.4 | 20.5 | 22.8 | 11.8 | 14.4 | 12.6 | 1 |
| Low-diet av...... | M. | 202 | 227 | 213 | 201 | ..... | 231 | 241 | ..... | 201 | 221 | 191 | 177 | 202 | 179 | 20 |
| | S.D. | 37 | 47 | 33 | 35 | ..... | 70 | 71 | ..... | 34 | 45 | 42 | 24 | 38 | 28 | 3 |
| | C. | 18.1 | 20.4 | 15.2 | 17.1 | ..... | 30.2 | 29.4 | ..... | 16.9 | 20.1 | 21.8 | 13.5 | 18.7 | 15.3 | 1 |

The available data for Squads A and B are plotted in figure 112. The two upper curves are for the variability and they show about 20 per cent for both squads in the first two experiments. In the third experiment with each squad there was a definite increase which, with Squad A, was to about 25 per cent. As seen in table 167, several men in Squad A showed unusually high variabilities in that experiment, as, for example: 34.5, 34.6, and 37 for *Kon*, *Pec*, and *Tom*. These values are high enough to account for this fluctuation. With Squad B the percentage for the third experiment was 21.7. This is not a large

[1]The fragmentary data for Squad A on November 11 are due to a technical difficulty in the apparatus; the subjects were in no way to blame.

to and including December 9. In the last 2 experiments there was a definite, accumulative decline. This agrees very well with the findings for the general averages of the same squad on the same dates. It therefore appears that the eye-reaction time according to the technique here employed was not changed in any significant way by the reduced diet. According to the present standards our averages and the variability values with the fluctuations in these are well within normal limits.

TABLE 169.—*Squad A—Average of shortest eye reactions.*
[Values in σ.]

| Date. | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pes. | Pec. | Spe. | Tom. | Ves. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. | | | | | | | | | | | | | |
| Oct. 28.... | 244 | 146 | 179 | 145 | 138 | 188 | 173 | 178 | 181 | 190 | 155 | 183 | 172 |
| Nov. 11.... | ..... | ..... | ..... | ..... | ..... | ..... | 180 | 193 | ..... | 209 | ..... | 170 | ..... |
| Nov. 25.... | 176 | 139 | 164 | 157 | 168 | 180 | 171 | 167 | 171 | 173 | 158 | 167 | 165 |
| Dec. 9.... | 158 | 134 | 156 | 152 | 141 | 155 | 170 | 178 | 160 | 184 | 157 | 158 | 156 |
| 1918. | | | | | | | | | | | | | |
| Jan. 13.... | 177 | 142 | 144 | 164 | 146 | 181 | 169 | 186 | 176 | ..... | 156 | 156 | 165 |
| Jan. 27.... | 180 | ..... | 135 | 169 | 156 | 162 | 174 | 183 | 167 | ..... | 162 | 159 | 168 |

TABLE 170.—*Squad B—Average of shortest eye reactions.*
[Values in σ.]

| Date. | Fis. | Har. | How. | Ham. | McM. | Kim. | Lon. | Mac. | Sch. | Liv. | Sne. | Tho. | Van. | Wil. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. | | | | | | | | | | | | | | | |
| Nov. 4........ | 163 | 208 | 215 | 168 | 178 | .... | 197 | 191 | .... | 194 | 170 | 192 | 154 | 163 | 182 |
| Nov. 18........ | 167 | .... | 212 | 157 | 141 | .... | 180 | 156 | .... | 194 | 178 | 181 | 163 | 150 | 176 |
| Dec. 16........ | .... | 197 | 192 | 154 | 151 | .... | 173 | .... | .... | 187 | 155 | 158 | 163 | 137 | 168 |
| 1918. | | | | | | | | | | | | | | | |
| Jan. 14........ | 155 | 171 | 185 | 153 | 161 | .... | 180 | .... | 160 | 172 | 150 | 156 | 156 | 150 | 163 |
| Jan. 20........ | 165 | 174 | 176 | 161 | 162 | .... | 170 | .... | 160 | 166 | 137 | 145 | 159 | 142 | 160 |

## (10) REACTION TIME FOR SPEAKING 4-LETTER WORDS.

When a list of 25 familiar 4-letter words is presented in chance order the reaction time for responding to such stimuli is approximatel twice that of the eye-reaction time.[1] In tables 171 and 172 fo Squads A and B, respectively, the average reaction time, with th standard deviation and the coefficient of variability, is recorded fo each subject and for each session. The word reactions were firs taken at the second experimental session with each squad, hence ther are no normal values for Squad A. There are 4 normal dates for Squa

[1]As was shown by Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 100, ther is an instrumental latency with this exposure apparatus amounting to 37 σ. The values whic have been entered in the tables are simply for comparative purposes, and this factor has n been subtracted from them. The same is true of the published eye reaction data, where th instrumental latency is 20 σ. (See footnote, p. 163.)

B. Word reactions were taken on 9 evenings with Squad A. The averages for these individual subjects are at the bottom of table 171 and range from 415 σ for *Bro* to 597 σ for *Can*, with a total average for the 10 men of 486 σ. The coefficient of variability for the individual series of reactions is from 7 to 13 per cent of the reaction time, the average for the 10 subjects being 9.3 per cent. These average figures for Squad A compare fairly well with the results found with normal

TABLE 171.—*Squad A—Time and variability of word reaction.*
[M. in σ; S. D. in σ; and C. in per cent.]

| Date. | Reaction. | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pea. | Pec. | Spe. | Tom. | Ves. | Fre. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. | | | | | | | | | | | | | | | |
| Oct. 13.. | M. | 444 | 679 | ..... | 490 | 457 | 513 | 473 | 574 | 468 | 488 | 454 | 476 | 441 | 503 |
| | S.D. | 34 | 82 | ..... | 49 | 63 | 64 | 77 | 62 | 54 | 46 | 45 | 58 | 51 | 58.8 |
| | C. | 7.8 | 12.1 | ..... | 10.0 | 13.8 | 13.8 | 16.3 | 10.8 | 11.5 | 9.4 | 9.9 | 12.2 | 11.6 | 11.8 |
| Oct. 27.. | M. | 413 | 658 | 550 | 472 | 439 | 512 | 458 | 527 | 440 | 554 | 465 | 470 | ..... | 485 |
| | S.D. | 45 | 69 | 125 | 35 | 38 | 40 | 43 | 53 | 53 | 84 | 57 | 38 | ..... | 47.1 |
| | C. | 10.9 | 10.5 | 22.7 | 7.4 | 8.7 | 7.8 | 9.4 | 10.1 | 12.0 | 15.2 | 12.3 | 8.1 | ..... | 9.7 |
| Nov. 10.. | M. | 436 | 566 | 506 | 478 | 443 | 491 | 439 | 507 | 452 | 485 | 530 | 475 | ..... | 482 |
| | S.D. | 45 | 40 | 43 | 27 | 28 | 47 | 31 | 54 | 67 | 32 | 87 | 50 | ..... | 47.6 |
| | C. | 10.3 | 7.1 | 8.5 | 5.7 | 6.3 | 9.6 | 7.1 | 10.6 | 14.8 | 6.6 | 16.4 | 10.5 | ..... | 9.8 |
| Nov. 24.. | M. | 414 | 576 | 514 | 455 | 443 | 499 | 518 | 514 | 483 | 508 | 438 | 468 | ..... | 481 |
| | S.D. | 28 | 36 | 46 | 56 | 29 | 33 | 64 | 52 | 68 | 40 | 40 | 23 | ..... | 42.9 |
| | C. | 6.8 | 6.3 | 9.0 | 12.3 | 6.6 | 6.6 | 12.3 | 10.1 | 14.1 | 7.9 | 9.1 | 4.9 | ..... | 8.9 |
| Dec. 8.. | M. | 403 | 578 | 505 | 477 | 429 | 499 | 478 | 522 | 460 | 492 | 438 | 448 | ..... | 473 |
| | S.D. | 30 | 37 | 62 | 43 | 34 | 48 | 54 | 41 | 72 | 37 | 31 | 31 | ..... | 42.1 |
| | C. | 7.5 | 6.4 | 12.3 | 9.0 | 7.9 | 9.6 | 11.3 | 7.9 | 15.7 | 7.5 | 7.1 | 6.9 | ..... | 8.9 |
| Dec. 19.. | M. | 399 | 583 | 506 | 464 | 435 | 504 | 482 | 515 | 466 | ..... | 457 | 456 | ..... | 476 |
| | S.D. | 26 | 29 | 49 | 40 | 21 | 36 | 49 | 41 | 64 | ..... | 57 | 26 | ..... | 38.9 |
| | C. | 6.5 | 5.0 | 9.7 | 8.6 | 4.8 | 7.1 | 10.2 | 8.0 | 13.7 | ..... | 12.5 | 5.7 | ..... | 8.2 |
| 1918. | | | | | | | | | | | | | | | |
| Jan. 12.. | M. | 397 | 568 | 501 | 477 | 463 | 565 | 556 | 549 | 507 | ..... | 453 | 468 | ..... | 500 |
| | S.D. | 28 | 36 | 45 | 44 | 20 | 47 | 50 | 60 | 61 | ..... | 34 | 49 | ..... | 42.9 |
| | C. | 7.1 | 6.3 | 9.0 | 9.2 | 4.3 | 8.3 | 9.0 | 10.9 | 12.0 | ..... | 7.7 | 10.5 | ..... | 8.5 |
| Jan. 26.. | M. | 401 | 595 | 540 | 474 | 449 | 543 | 574 | 510 | 476 | ..... | 547 | 451 | ..... | 502 |
| | S.D. | 38 | 57 | 40 | 50 | 34 | 44 | 62 | 44 | 60 | ..... | 75 | 34 | ..... | 49.8 |
| | C. | 9.5 | 9.6 | 7.4 | 10.5 | 7.6 | 8.1 | 10.8 | 8.6 | 12.6 | ..... | 13.7 | 7.5 | ..... | 9.8 |
| Feb. 2.. | M. | 427 | 566 | 532 | 427 | 449 | 489 | 518 | 487 | 469 | ..... | 487 | 430 | ..... | 475 |
| | S.D. | 20 | 53 | 64 | 34 | 21 | 41 | 40 | 43 | 43 | ..... | 43 | 45 | ..... | 38.3 |
| | C. | 4.7 | 9.4 | 12.0 | 8.0 | 4.7 | 8.4 | 7.7 | 8.8 | 9.2 | ..... | 8.8 | 10.5 | ..... | 8.0 |
| Low-diet av..... | M. | 415 | 597 | 519 | 468 | 445 | 513 | 500 | 523 | 469 | 505 | 474 | 460 | ..... | 486 |
| | S.D. | 33 | 49 | 59 | 42 | 32 | 44 | 52 | 50 | 60 | 48 | 52 | 39 | ..... | 45.4 |
| | C. | 7.9 | 8.1 | 11.3 | 9.0 | 7.2 | 8.8 | 10.5 | 9.5 | 12.8 | 9.3 | 10.8 | 8.5 | ..... | 9.3 |

subjects and during normal sessions by Dodge and Benedict,[1] who report the average reaction time for a group of normal subjects as 455 σ and the average mean variation[2] about 8.0 per cent of the average latency.

Individual subjects show homogeneous averages from experiment to experiment. For example, with *Kon*, the reaction times range within

[1] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 106.

[2] Dodge and Benedict use mean variation and not standard deviation which is larger than the former (S. D. = 1.253 M. V.). If the 8.0 per cent be multiplied by 1.25 to place it on the same basis with our coefficient of variability, we have 10 per cent to compare with 9.3 for the low-diet research.

TABLE 172.—*Squad B—Time and variability of word reaction.*
[M. in σ; S. D. in σ; and C. in per cent.]

10 per cent of each other. They are, beginning at the first session with this subject (October 27) 550, 506, 514, 505, 506, 501, 540, 532 σ, with a total average of 519 σ and an average variability of 11 per cent.

The results are compared in figure 113, in which curves for both squads and for all three factors of the table, that is, average reaction time, standard deviation, and coefficient of variability, are presented. Squad B shows decidedly more fluctuation from experiment to experiment in the average reaction time than is found with Squad A. They would seem to have done poorly in the first and second trials with this measurement as compared with Squad A, particularly so when it is considered that the data of Squad A, in comparison to that of Dodge and Benedict, show that these men were somewhat slow in these reactions. Squad B did poorly in their last normal experiment (January 5) and on the three low-diet dates made their best records, *i. e.*, 468, 478, and 476. Squad A shows, on the contrary, uniform results up to and including December 19. The two sessions of January 12 and 26 are remarkably poor for this group, being almost at the same level as

their first experiment on word reactions. On February 2 the men returned to the level of their December reaction averages.

The standard deviation was largest for both groups at their first session and fairly uniform beyond that, with the exception of a definite increase for Squad A on January 26. As shown in the lowest pair of curves, the standard deviation is about the same per cent of the average reaction time for both groups. The curves run remarkably close together. As might be expected, the percentage variability was largest at the first, that is, on October 13 and November 3 for Squads A and B. After that it remained between 8 and 10 per cent.

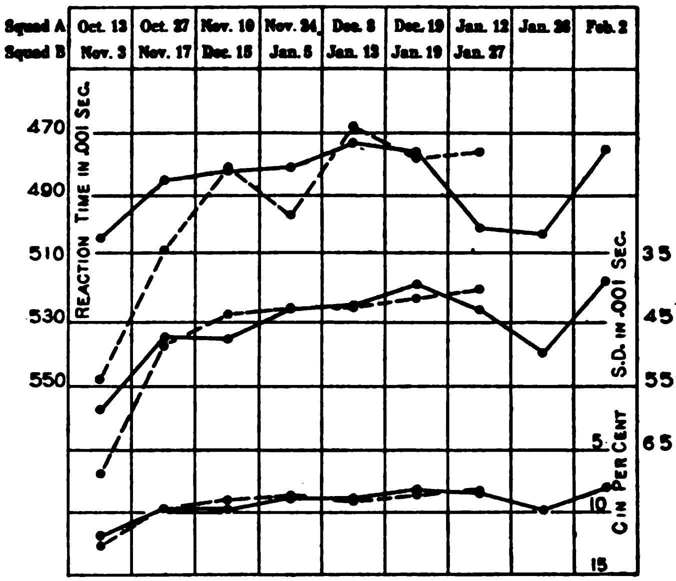



FIG. 113.—Word-reaction time and its variability.
Solid lines represent Squad A, and broken lines Squad B.

The record for January 26 shows a depression. We conclude that the low-diet condition produced no definite change in the general group averages or in the variability of the latency in the word-reaction measurement. In general the results tended to be somewhat poorer following the Christmas vacation.

#### (11) CONTINUOUS DISCRIMINATION AND REACTION IN FINDING SERIAL NUMBERS.

The total time required to find and point out the numbers 1 to 50 in proper order and without skipping any is shown for both squads in tables 173 and 174. Each squad began this test at their second experimental session, *i. e.*, the second time they came to Boston. There is thus no normal for Squad A. Many of the individual differences between the members of Squad A which were found in the other measurements are also observable here. Obviously, the best scores are

those which represent the shortest time. The best averages for A are for *Bro*, *Tom*, and *Vea*, with scores of 127, 122, and 132 seconds, respectively. Men who required a conspicuously long time to perform the test were *Spe*, *Mon*, and *Pec*, who have averages of 183, 168, and 167, respectively. *Spe* did not have so much opportunity for practice as the others. Thus the test brings out the usual individual differences. It required 2 to 3 minutes, the average for all subjects being 147 seconds. Squad B, as shown in table 174, was definitely slower in this test than A, both in the normal and the low-diet averages. Several of the men have average scores of 200 seconds or longer. The normal average is 194 seconds, the low-diet average 178 seconds. While the average of 194 might be considered slow because of the fewer practice occasions and the longer intervals which separated them, this condition does not apply in the three reduction dates, January 13, 19, and 27, which were preceded by ample opportunity for practice. It is therefore clear that the men of Squad B were slower in this test than the subjects in Squad A.

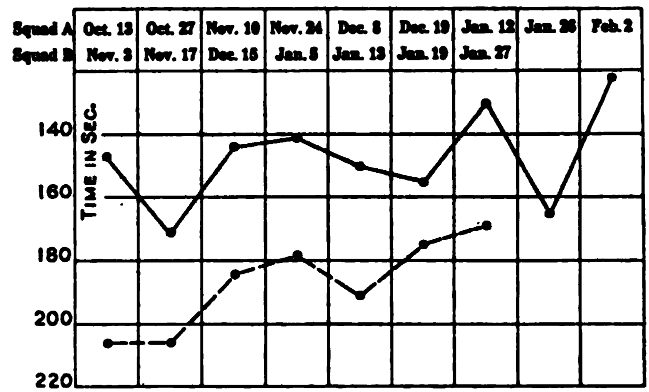



FIG. 114.—Average discriminatory reaction time for finding and pointing to serial numbers.

Solid line curve represents Squad A, and broken curve Squad B.

The averages for both squads on the different dates are compared in figure 114. Squad B is definitely below Squad A; there is somewhat

TABLE 173.—*Squad A—Reaction time for finding serial numbers.*

[Values in seconds.]

| Date. | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy | Pes. | Pec. | Spe. | Tom. | Vea. | Fre. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. | | | | | | | | | | | | | | |
| Oct. 13 | 111 | 128 | .... | 124 | 162 | 153 | 182 | 155 | 202 | 215 | 146 | 108 | 160 | 147 |
| Oct. 27 | 154 | 139 | 201 | 185 | 187 | 185 | 240 | 196 | 154 | 211 | 119 | 150 | .... | 171 |
| Nov. 10 | 121 | 172 | 202 | 154 | 105 | 140 | 178 | 131 | 183 | 168 | 124 | 129 | .... | 144 |
| Nov. 24 | 116 | 139 | 154 | 146 | 132 | 163 | 191 | 166 | 140 | 162 | 96 | 116 | .... | 141 |
| Dec. 8 | 151 | 145 | 147 | 137 | 155 | 205 | 156 | 106 | 177 | 158 | 132 | 132 | .... | 150 |
| Dec. 19 | 135 | 154 | 148 | 179 | 134 | 131 | 196 | 167 | 148 | .... | 150 | 157 | .... | 155 |
| 1918. | | | | | | | | | | | | | | |
| Jan. 12 | 109 | 120 | 146 | 137 | 145 | 117 | 125 | 150 | 173 | .... | 106 | 116 | .... | 130 |
| Jan. 26 | 147 | 161 | 162 | 142 | 155 | 234 | 146 | 220 | 186 | .... | 131 | 126 | .... | 165 |
| Feb. 2 | 101 | 122 | 148 | 133 | 96 | 184 | 112 | 88 | 142 | .... | 95 | 150 | .... | 122 |
| Low-diet average | 127 | 142 | 164 | 149 | 141 | 168 | 158 | 153 | 167 | 183 | 122 | 132 | 160 | 147 |

prise to find that in the first normal measurement for this threshold Squad B, the average of the 10 men is 58.2'', that is, 10'' lower than t average for the normal group of prospective aviators, the personnel which was supposedly selected with some reference to keen visic Naturally this factor of vision was a matter of pure chance in the sel tion of the personnel for Squad B. These first averages show alm the same range as the normal series of 1917, that is, the range for B 41'' to 110''. The latter figure (the record for *Mac*) is not included the average. If included, it would raise the average somewhat, b not to the level of the average for the normal series of 1917. It regretted that no normal records are available for Squad A; their fi

TABLE 175.—*Squad A—Visual efficiency and its mean variation.*
[Values given in seconds on the arc of vision.]

[1] Subject commonly wore glasses but not when tested.
[2] In the vertical axis *Can* has a threshold of about 48''; it is his pronounced astigmatism, the fore, that accounts for large M. V. of this subject.
[3] The subject's father was a visitor in the room when these measurements were taken.

measurement for this threshold was on October 13; this was the fi observation after food reduction, which began on October 4. T average for the 10 men on this date is 86.2'', and would not materially different if *Spe* and *Fre* were included. According to t only available normals, this seems to be high.

The individual values in tables 175 and 176 are, in each case, t average of from 12 to 20 threshold determinations, distributed abo equally between the four axes which were used, as outlined on pa 175. The mean variation computed by taking all of an individual

observations on one evening and considering them as one group, is partly a measure of astigmatism as well as of true variability. The number of observations made at each axis was too small for satisfactory determination of a separate mean or standard deviation. The average mean variation, so-called, is found to be 8.7″ for Squad A (see lower right-hand corner of table 175). It is somewhat smaller in the case of Squad B, being 5.3″ for their normal measurements and 4.8″ for their low-diet averages. (See table 176.)

TABLE 176.—*Squad B—Visual efficiency and its mean variation.*
[Values given in seconds on the arc of vision.]

| ate. | Acuity. | Fis. | Har. | How. | Ham. | McM.[1] | Kim. | Lon. | Mac.[2] | Sch. | Liv. | Sne. | Tho. | Van. | Wil. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 917. | | | | | | | | | | | | | | | | |
| . 3.. | M. | 50 | 52 | 41 | 46 | 67 | ..... | 57 | 110 | ..... | 79 | 78 | 68 | 51 | 60 | 58.2 |
| | M. V. | 2.3 | 2.9 | 2.6 | 3.7 | 4.2 | ..... | 5.8 | 10.5 | ..... | 9.2 | 12.5 | 4.4 | 3.3 | 6.3 | 5.30 |
| . 17.. | M. | 44 | 84 | 63 | 45 | 62 | ..... | 83 | 97 | ..... | 85 | 45 | 80 | 47 | 72 | 64.8 |
| | M. V. | 3.1 | 8.7 | 6.8 | 3.3 | 5.1 | ..... | 9.4 | 7.7 | ..... | 5.0 | 3.4 | 7.8 | 5.8 | 6.2 | 5.95 |
| . 15.. | M. | ..... | 78 | 41 | 41 | 55 | ..... | 72 | 88 | ..... | 84 | 82 | 87 | 42 | 60 | 65.2 |
| | M. V. | ..... | 9.3 | 1.7 | 1.9 | 5.7 | ..... | 5.5 | 7.5 | ..... | 8.4 | 5.3 | 3.7 | 5.2 | 8.6 | 5.51 |
| 918. | | | | | | | | | | | | | | | | |
| . 5.. | M. | 44 | 81 | 49 | [3]45 | 64 | (4) | ..... | ..... | 89 | 91 | 46 | 91 | 43 | 58 | 61.0 |
| | M. V. | 2.8 | 9.8 | 3.5 | 1.6 | 5.7 | ..... | ..... | ..... | 6.5 | 5.3 | 2.9 | 3.7 | 5.3 | 4.4 | 4.37 |
| mal av. | M. | 46.0 | 73.8 | 48.5 | 44.3 | 62.0 | ..... | 70.7 | 98.3 | 89.0 | 84.8 | 62.8 | 81.5 | 45.8 | 62.5 | 62.3 |
| | M. V. | 2.7 | 7.7 | 3.7 | 2.6 | 5.2 | ..... | 6.9 | 8.6 | 6.5 | 7.0 | 6.0 | 4.9 | 4.9 | 6.4 | 5.28 |
| . 13.. | M. | 40 | 90 | 43 | 40 | ..... | 64 | 70 | ..... | 81 | 78 | 70 | 83 | 42 | 67 | 62.3 |
| | M. V. | 2.2 | 4.9 | 9.7 | 7.2 | ..... | 7.8 | 6.1 | ..... | 4.9 | 5.5 | 8.6 | 7.6 | 2.5 | 7.6 | 6.19 |
| . 19.. | M. | 41 | 80 | 38 | 36 | ..... | 53 | 74 | ..... | 83 | 89 | 38 | 84 | 40 | 61 | 58.1 |
| | M. V. | 1.5 | 6.3 | 1.8 | 2.8 | ..... | 4.4 | 4.7 | ..... | 5.8 | 6.4 | 2.9 | 5.5 | 1.7 | 5.2 | 3.88 |
| . 27.. | M. | 40 | 74 | 39 | 44 | ..... | 54 | 72 | ..... | 86 | 83 | [5]32 | 79 | 40 | 62 | 56.5 |
| | M. V. | 1.9 | 4.0 | 3.4 | 7.9 | ..... | 4.6 | 4.5 | ..... | 7.0 | 6.1 | 1.9 | 4.6 | 3.5 | 4.0 | 4.18 |
| -diet v...... | M. | 40.3 | 61.3 | 40.0 | 40.0 | ..... | 57.0 | 72.0 | ..... | 83.3 | 83.3 | 46.7 | 82.0 | 40.7 | 63.3 | 59.0 |
| | M. V. | 1.9 | 5.1 | 5.0 | 6.0 | ..... | 5.6 | 5.1 | ..... | 5.9 | 6.0 | 4.5 | 5.9 | 2.6 | 5.6 | 4.75 |

[1] Subject commonly wore glasses but not when tested.
[2] The right eye was used in the test as with the other subjects, but *Mac* informs us that he has better vision with his left eye.
[3] *Ham* complained that his eyes were tired from reading on the train while coming to Boston.
[4] This was the first session for *Kim* and this measurement was not given for lack of time.
[5] *Sne* said he could see the fixation dot better in this test than in any previous experiment.

In figure 115 the mean variations (see the two lower curves) are very consistent from experiment to experiment, with a slight increase for Squad B at the time of the first reduction date (January 13). The curve for Squad A is definitely and consistently below that for Squad B, with two slight depressions on October 27 and November 24 and a tendency to smaller variations near the close of the series of experiments, but these fluctuations are certainly not larger than might normally occur.

The average thresholds for the two groups, as expressed in degrees on the arc of vision and shown in the upper curves in figure 115, maintain from October 27 and November 17 about the same relative levels

with continuous improvement. The wide and opposed variations in the thresholds shown by the two squads at their first measurements cannot be satisfactorily explained. In the case of Squad B, the rise in the threshold, shown on November 17, is of course partly due to the records for *Har*, *How*, and *Lon*, as shown in table 176. However, the average threshold does not improve on December 15, but is, in fact, slightly higher on this date, for some of the subjects, particularly *Sne*, show an increase. Considering Squad B's successive averages for November 17, December 15, January 5, and January 13, it seems very probable that the average threshold for November 3, the first time this measurement was taken, is very low for some chance reason which is not revealed. This conclusion seems further justifiable in view of the fact that this threshold for Squad B, as was pointed out earlier, is below the average for the normal group of 1917.

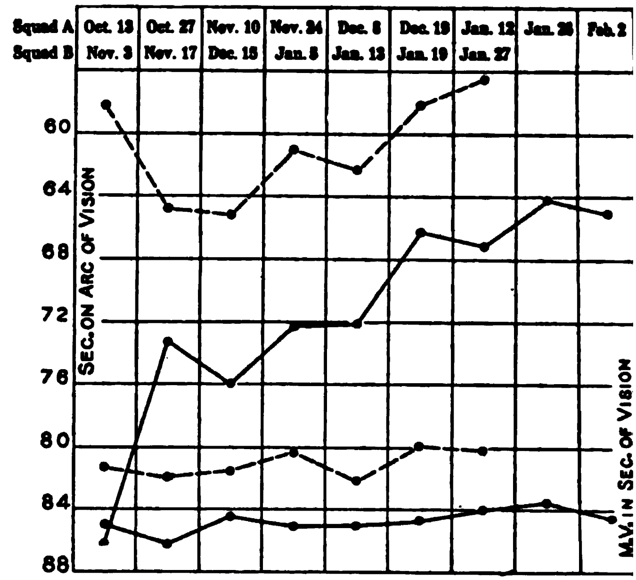



Fig. 115.—Visual efficiency and its mean variation. Solid lines represent Squad A, and broken lines Squad B.

With Squad A the first average threshold is very high, and indeed, by present standards, seems abnormally high. It is of course associated with food reduction, although on this particular dat (October 13) the subjects received an average of 1,993 net calories pe man, an amount which was 250 calories above the average for the 9 day during the low-diet period on which the subjects of Squad A came t Boston. An examination of table 175 for Squad A would indicate tha this high threshold for October 13 is due principally to the subjects *Pe* *Can*, and *Bro*. The first designated subject was poor in threshol measurements, as will be seen by examining his record for the ele trical threshold. *Can* commonly wore glasses and apparently foun some difficulty in adjusting himself to taking the test without ther No explanation can be given for the relatively high threshold of *Br* who later in the series showed very consistent results and also a ve low threshold; furthermore his mean variation was usually sma

the average being 3.1 seconds. The higher threshold for October 13 may be partly due to the food reduction. The poor result for November 10 corresponds with the lowest average net energy figure for any of the experimental dates (see table 146). These correspondences do not definitely prove that the reduced diet raised the threshold for visual efficiency with Squad A, and as the results for B give no clear substantiation, the findings appear to be negative. The difference in level between the two squads can hardly be assigned as a low-diet effect, although if each squad were several times larger, this might be significant.

### (13) SENSORY THRESHOLD FOR ELECTRIC SHOCK.

This measurement taken in the same way and employing the same apparatus, with the exception of the electrodes,[1] was used in the normal series of 1917. The threshold range shown by the 63 normal men was from 46 to 195 volts. The subjects were distributed in threshold ranges as follows:

| 50 or below. | 51 to 75. | 76 to 100. | 101 to 125. | 126 to 150. | 151 to 175. | 176 to 200. |
|---|---|---|---|---|---|---|
| 1 | 3 | 13 | 23 | 16 | 5 | 2 |

The distribution is seen to be a fairly normal one, the mode is clearly at 101 to 125 volts, within which range 23 of the subjects came. The average for the whole group was 117.3 volts, with a standard deviation for the series of 63 subjects of 30 volts.

With the above values in mind as normals for initial measurements, we may turn to a consideration of the data for Squads A and B, as shown in tables 177 and 178. For the first experiment, September 29, the 10 men of Squad A show an average of 118 volts as compared to 117 volts for the normal series of 1917. That this close correspondence is not entirely accidental is proved by the fact that *Kon*, *Spe*, and *Fre* of Squad A, whose values are not included in the average, show a similar average of 123 volts. The 10 men of Squad B in their first experiment had an average of 126 volts, the one man whose records are not in the average (*Mac*) having a value of 101 volts. It appears that in initial measurements of the threshold for electric shock, with the apparatus and technique here employed, a normal average value of about 120 volts may be reasonably expected. Squad A (see table 177) for the nine experiments of October 13 to February 2, has also a total average for the ten men of exactly 120 volts, suggesting that there has been very little, if any, improvement in contrast to the visual threshold results throughout the period of measurements. The averages for the individual subjects, exclusive of September 29, range from 69 volts for *Moy* to 172 volts for *Mon*.

[1]The electrodes were also of the non-polarizable type, but separate vessels were provided for each finger; the vessels being quite small, the level of the solution was adjusted for each subject. The normal measurements were made in the summer and the salt solution was of room temperature. It was unnecessary to warm it by the electric heater.

TABLE 177.—*Squad A—Electrical threshold and its variability.*
[M. and S. D. in volts; C. in per cent.]

The average individual threshold determinations for the members Squad B demonstrate no peculiarity which differentiates them fr the values which have been discussed for A. The group average f the 5 normal experiments is 115 volts as compared to the value of 1 volts for the first session. This indicates some improvement. T average for the 3 low-diet experiments is 123 volts, which is fairly cl to the average for the first experiment.

In connection with these threshold averages, and more particula with the variability values, a matter of experimental procedure d serves consideration. In the electrical-threshold determination was desirable to secure an average, if possible, that had statisti significance. With this apparatus, stimuli could be presented abo every 2.5 seconds. If one began at a value which was easily felt a proceeded with the series by decreasing the voltage carefully in sm steps to that which was the threshold value, it required about 1 min

TABLE 178.—*Squad B—Electrical threshold and its variability.*
[M. and S. D. in volts; C. in per cent.]

| ate. | Threshold. | Fis. | Har. | How. | Ham. | McM. | Kim. | Lon. | Mac. | Sch. | Liv. | Sne. | Tho. | Van. | Wil. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 917. | | | | | | | | | | | | | | | | |
| . 6.. | M. | 228 | 133 | 92 | 124 | ..... | ..... | 164 | 101 | ..... | 110 | 89 | 77 | 126 | 116 | 126 |
| | S.D. | 4.0 | 2.8 | 2.8 | 2.8 | ..... | ..... | 2.0 | 5.7 | ..... | 0.0 | 4.0 | 2.8 | 2.0 | 2.8 | 2.6 |
| | C. | 1.8 | 2.1 | 3.0 | 2.3 | ..... | ..... | 1.2 | 5.6 | ..... | 0.0 | 4.5 | 3.6 | 1.6 | 2.4 | 2.3 |
| r. 3.. | M. | 164 | 126 | 89 | 135 | 109 | ..... | 122 | 107 | ..... | 106 | 95 | 75 | 127 | 109 | 115 |
| | S.D. | 10.0 | 6.6 | 4.0 | 6.6 | 4.5 | ..... | 8.2 | 3.5 | ..... | 4.5 | 4.9 | 8.5 | 9.6 | 2.8 | 6.6 |
| | C. | 6.1 | 5.2 | 4.5 | 4.9 | 4.1 | ..... | 6.7 | 3.3 | ..... | 4.2 | 5.2 | 11.3 | 7.6 | 2.6 | 5.8 |
| r. 17.. | M. | 189 | 134 | 76 | 144 | 113 | ..... | 123 | 90 | ..... | 87 | 94 | 79 | 145 | 98 | 117 |
| | S.D. | 4.0 | 4.9 | 3.5 | 4.0 | 4.9 | ..... | 6.0 | 3.5 | ..... | 4.5 | 5.7 | 4.0 | 6.3 | 2.8 | 4.6 |
| | C. | 2.1 | 3.7 | 4.6 | 2.8 | 4.3 | ..... | 4.9 | 3.9 | ..... | 5.2 | 6.1 | 5.1 | 4.3 | 2.9 | 4.2 |
| . 15.. | M. | ..... | 124 | 104 | 128 | 84 | ..... | 129 | 83 | ..... | 83 | 87 | 93 | 135 | 104 | 110 |
| | S.D. | ..... | 6.3 | 2.8 | 4.0 | 8.7 | ..... | 4.9 | 4.0 | ..... | 7.8 | 9.6 | 4.5 | 11.8 | 6.0 | 6.4 |
| | C. | ..... | 5.1 | 2.7 | 3.1 | 10.4 | ..... | 3.8 | 4.8 | ..... | 9.4 | 11.0 | 4.8 | 8.7 | 5.8 | 6.0 |
| 918. | | | | | | | | | | | | | | | | |
| . 5.. | M. | 185 | 120 | 73 | 134 | 120 | ..... | ..... | ..... | 193 | 120 | 73 | 104 | 146 | 106 | 118 |
| | S.D. | 9.4 | 4.0 | 3.5 | 6.6 | 13.0 | ..... | ..... | ..... | 6.0 | 7.2 | 12.0 | 4.5 | 7.8 | 2.8 | 6.4 |
| | C. | 5.1 | 3.3 | 4.8 | 4.9 | 10.8 | ..... | ..... | ..... | 3.1 | 6.0 | 16.4 | 4.3 | 5.3 | 2.6 | 5.9 |
| mal | | | | | | | | | | | | | | | | |
| v...... | M. | 192 | 127 | 87 | 133 | 107 | ..... | 135 | 95 | 193 | 101 | 88 | 86 | 136 | 107 | 115 |
| | S.D. | 6.9 | 4.9 | 3.3 | 4.8 | 7.8 | ..... | 5.3 | 4.2 | 6.0 | 4.8 | 7.3 | 4.9 | 7.5 | 3.4 | 5.3 |
| | C. | 3.8 | 3.9 | 3.9 | 3.6 | 7.4 | ..... | 4.2 | 4.4 | 3.1 | 4.6 | 8.6 | 5.8 | 5.5 | 3.3 | 4.8 |
| . 13.. | M. | 176 | 112 | 105 | 150 | ..... | 97 | 121 | ..... | 207 | 127 | 59 | 77 | 149 | 125 | 120 |
| | S.D. | 10.0 | 4.5 | 4.5 | 4.5 | ..... | 4.5 | 14.7 | ..... | 15.7 | 7.8 | 7.5 | 4.0 | 7.5 | 4.5 | 7.0 |
| | C. | 5.7 | 4.0 | 4.3 | 3.0 | ..... | 4.6 | 12.1 | ..... | 7.6 | 6.1 | 12.7 | 5.2 | 5.0 | 3.6 | 6.2 |
| . 19.. | M. | 207 | 152 | 92 | 162 | ..... | 108 | 135 | ..... | 141 | 108 | 118 | 80 | 161 | 147 | 136 |
| | S.D. | 5.7 | 7.2 | 4.5 | 7.2 | ..... | 4.9 | 3.5 | ..... | 6.3 | 9.2 | 5.3 | 3.5 | 14.6 | 7.5 | 6.8 |
| | C. | 2.8 | 4.7 | 4.9 | 4.4 | ..... | 4.5 | 2.6 | ..... | 4.5 | 8.5 | 4.5 | 4.4 | 9.1 | 5.1 | 5.1 |
| . 27.. | M. | 158 | 108 | 109 | 120 | ..... | 100 | 121 | ..... | 158 | 100 | 99 | 75 | 124 | 123 | 114 |
| | S.D. | 8.7 | 11.3 | 3.5 | 8.2 | ..... | 4.0 | 5.7 | ..... | 11.8 | 6.3 | 6.0 | 4.9 | 12.6 | 8.0 | 7.5 |
| | C. | 5.5 | 10.5 | 3.2 | 6.8 | ..... | 4.0 | 4.7 | ..... | 7.5 | 6.3 | 6.1 | 6.5 | 10.2 | 6.5 | 6.6 |
| r-diet | | | | | | | | | | | | | | | | |
| v...... | M. | 180 | 124 | 102 | 144 | ..... | 102 | 126 | ..... | 169 | 112 | 92 | 77 | 145 | 132 | 123 |
| | S.D. | 8.1 | 7.7 | 4.2 | 6.6 | ..... | 4.4 | 8.0 | ..... | 11.3 | 7.8 | 6.3 | 4.1 | 11.6 | 6.7 | 7.1 |
| | C. | 4.7 | 6.4 | 4.1 | 4.7 | ..... | 4.4 | 6.5 | ..... | 6.5 | 7.0 | 7.8 | 5.4 | 8.1 | 5.1 | 6.0 |

to reach and pass the threshold. Thus, at best, in the time available not more than 5 to 8 test series could be given. This is a somewhat small number to average. In supplement of the description of procedure, given on page 176, it should be made clear that following a preliminary series to determine the approximate value of the threshold, series lasting about 2 minutes were taken very near the threshold level with an effort to get as many responses in this vicinity as possible. The voltage was increased and decreased very gradually. If the subject responded two or three times in succession the voltage was gradually decreased to a point where he failed. If he failed to respond to two or three shocks which came through to his fingers, the voltage was gradually increased. In other words, a large number of shocks in increasing and decreasing series were given in succession. The subject, realizing that the shocks were all to be very close to his limit, concentrated his attention at those moments when the shock might be expected and responded to every one which he felt. The voltage

of every shock with response or failure to respond was recorded. elaborating the records, the average between successive volt records when the subject responded in one case and in the next c failed to respond, was arbitrarily considered a threshold determi tion. For example: if a man responded to a shock voltage of 104 v and had been responding to shocks of this strength, or stronger, a then failed to respond to a shock of 100 volts, the threshold determi tion was considered the average of 104 and 100, or 102 volts. Usua about 20 such determinations would occur in the records taken wit subject in the test period of one evening.

The average standard deviation for the individual series of deter nations on a single subject (see tables 177 and 178) is about 7.5 vo There are rather wide variations from this, that is, with Squad A th range from 2 to 20 volts. *Pea* has the largest average standa deviation (10.8 volts) of any man in Squad A. The smallest is co sistently found with *Moy* (4.3 volts), whose threshold was also t lowest average for the group. *Van* and *Sch*, of Squad B, have standa deviations of 11.6 and 11.3 volts, as averages for the reduction peri Their thresholds were, however, much higher than that for *P* being 145 and 169 volts, as compared with 100 volts. The standa deviation is usually about 6.5 per cent of the average threshold valu Squad B show slightly less than this, particularly in the average for t five normal experiments, the percentage for which is 4.8. The ceptional case, in the two squads, is that of *Pea* in Squad A, with average coefficient of variability of 11.1 per cent for the low-diet peri It is exceptional to find any other of the 25 subjects who compris these two squads showing a variability of as much as 10 per cent any date. The small average variability of both squads in their fi experiment is due to the much smaller number of threshold dete minations that were made on these dates, when the method was n the same as described in the paragraph above, but was identical wi that used in the normal series of 1917. The small variability with any individual series of threshold determinations makes this measu ment compare very favorably with any sensory threshold measureme with which we are familiar.

The fluctuations of the two sets of results throughout the gro of experiments are shown in figure 116. First it may be noted th the standard deviation and coefficient of variability are practical stationary from first to last and are at very nearly the same level f both squads, tending to be a little smaller with Squad B. There is slight increase in the standard deviation for October 27, Squad apparently due to unusually large deviations with *Tom*, *Ve* *Pec*, and *Mon*. Both squads show one marked depression (high threshold) during the period of the experiment. In the case of A th occurred at the first reduction date, October 13, when the average w

138 volts, as compared to the former average threshold of 118 volts, a rise in the threshold of 17 per cent; this change is three times as large as the average standard deviation. Seven of the 10 subjects show in their averages this change to a higher threshold at the time of the second experiment. It is of interest to compare this high electrical threshold on October 13, the first experiment after food reduction began, with the high visual threshold on the same date. (See figure 115.) There are two much smaller depressions in the curve, that is, on November 24 and February 2, but in general, a very even level obtains which is near that of the first and normal (September 29) experiment. Squad B began high at 126 volts, for October 6, which was largely due to the abnormally high threshold found for *Fis* of 228 volts. This was a value higher than any found among the 63 normal subjects of the

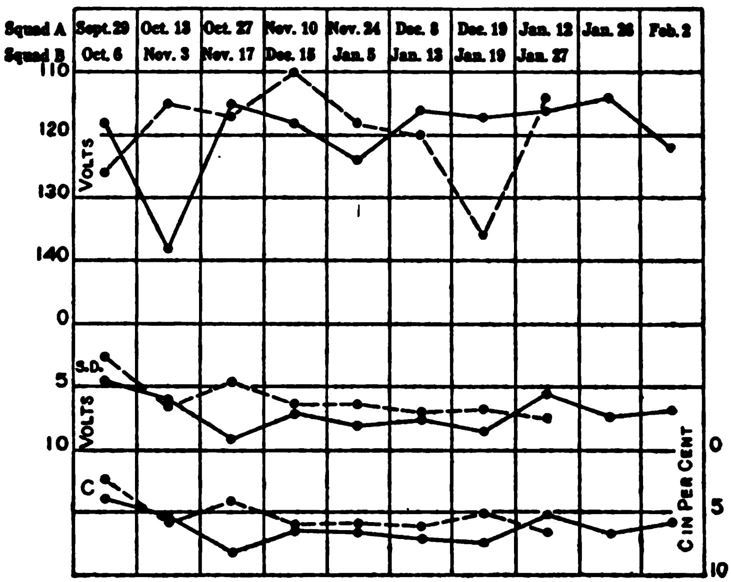



FIG. 116.—Electrical threshold averages and variability.

Solid line curves represent Squad A, and broken curves Squad B.

series of 1917 and considerably higher than succeeding values with this subject, although his general average is in the neighborhood of 190 volts, the limit of the supposedly normal range. Hence it seems that the improvement shown between the first and second experiments is partly to be discounted as an individual peculiarity. The date of January 5 has previously been noted in other measurements as showing results for Squad B somewhat below their average. The first two experiments during the low-diet period of Squad B, particularly the second one, show a markedly higher electrical threshold than even that of January 5, which is itself higher than that for the three

previous dates. The change is very similar to that which occurred in the second experiment with Squad A. On the last date for Squad B, January 27, the normal level was reached, but Squad A was not quite at their normal level in the last experiment.

The data with both squads appear to indicate that, coincident with the beginning of food reduction, the electrical threshold was increased in the neighborhood of 15 per cent, while the standard deviation and percentage of variability show no concomitant change. Threshold determinations on Squad B indicate what might reasonably be expected, *i. e.*, some improvement with practice. It would be surprising if the physiological threshold were reached without practice in this case of electrical stimulation. Squad A shows no such improvement with practice, and this lack we associate with the reduced diet.

### (14) SPEED OF THE EYE MOVEMENTS.

Of the measurements at present available, the motor coordination for successive horizontal eye movements is one of the best ndicators of the neuro-muscular condition.[1] The finger movements, as a motor process, compare very favorably with the eye movements, but in the case of the latter it is not so possible, if indeed it is at all possible, for the subject to influence them voluntarily. The time required for making a horizontal sweep of the eye through 40° on the arc of vision is almost a neuro-muscular constant for the individual and for his physiological or neuro-muscular condition.

Eye-movement records were taken with 63 men in the normal series of 1917. They were all recorded from the right eye and with the left eye covered.[2] The procedure was identical with that used in the low-diet research. Four series of records, *i. e.*, two plates (for illustrative records, see fig. 52) were made with each subject, as in the present investigation. The number of eye movements left or right which are available for counts in the case of a particular subject is usually 20. Therefore, the average figure for any man on any date is usually drawn from this number of counted movements. The range of eye-movement speed shown by the men in the normal series of 1917 is tabulated in table 179. The units are 0.001 second ($\sigma$) and the column headings in the table are self-explanatory. Two subjects show speeds for movements to the left which average 76 and 79 $\sigma$, respectively. These fall in the group division 71 to 80. The slqwest eye-movement times for left movement were the averages 141 and 148. The distribution between these high and low points is fairly characteristic of normal frequency. The mode is clearly at 101 to 110, 24 of the 63 subjects showing averages which came within this range. The total average for the left movement is 107.0 $\sigma$ and the standard deviation for the

[1]Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, pp. 146 and 262.
[2]There were a very few exceptions to this latter statement due to errors in the procedure.

series of 63 left movement averages is 13.9 $\sigma$, showing a coefficient of variability within the group of 13 per cent. The movements to the right fall within a narrower range than those for the left. The average fastest speed is 75, and the slowest 128. The distribution between these extremes is sensibly normal, the mode occurring at 91 to 100. The average for the whole series of 63 individual averages is 97.8 $\sigma$. The standard deviation is 11.7 $\sigma$ and the coefficient of variability for movements right therefore equals 12 per cent.

The measurements taken on the normal subjects during normal experiments by Dodge and Benedict in connection with their alcohol investigation gave the following results as averages of the first normal series for 7 subjects: Speed for movements to the left, 101 $\sigma$; for movements to the right 99 $\sigma$. There is fair agreement between these totally different groups of individuals.

With the subjects used by Dodge and Benedict, the eye movements were taken in the afternoon and evening. In the case of the normal series of 1917 the time of day was always between 7 and 10 p. m. and following a hearty supper. The measurements with the subjects on reduced diet were invariably taken in the morning and following the light breakfast at the Laboratory. The eye reactions and eye movements were successive measurements.

TABLE 179.—*Range of eye-movement speeds shown by a group of 63 normal men, series of 1917.*

[Records taken from the right eye and with the left eye covered.]

| Speed ranges for 40° movements, time unit 0.001 sec. | Distribution of 63 subjects. | |
|---|---|---|
| | Movements left. | Movements right. |
| 61 to 70 | 0 | 0 |
| 71 to 80 | 2 | 4 |
| 81 to 90 | 4 | 15 |
| 91 to 100 | 14 | 19 |
| 101 to 110 | 24 | 16 |
| 111 to 120 | 9 | 7 |
| 121 to 130 | 6 | 2 |
| 131 to 140 | 2 | 0 |
| 141 to 150 | 2 | 0 |

The average results for Squads A and B are given in tables 180 and 181. We have no normal records for Squad A. The first three dates, that is, November 4, 18, and December 16, for Squad B are normal in the sense that the diet had not then been reduced. November 4 (see table 181) shows an average for movements to the left of 95.1 $\sigma$, and for movements to the right of 88.9 $\sigma$. The time required for movements of 40° to the left, registration being from the right eye and with the left eye covered, is noted to be longer than similar movements to the right. As this is seen to be characteristic of the records for the low-diet research, it is prominent also in the averages of the normal series of 1917, and moreover in the normal records taken by Dodge and Benedict. The reason for this discrepancy between the time requirement for right and left movement can not be definitely assigned at this time. We have considerable data on the problem and it is under investigation at the Nutrition Laboratory. The averages for

left and right are, as in the case of the normal data of Dodge and Benedict, somewhat below the values shown for the 63 men of the series of 1917. This may be a mere matter of chance, or on the other hand partly due to the time of day of taking the records. Undoubtedly sleepiness slows down the eye movements.[1] The variability in the

TABLE 180.—*Squad A—Eye movement speed and its variability.*

[L. and R. designate left and right movements, M. and S. D. in σ, and C. in per cent.]

| Date. | Eye. | Speed. | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pea. | Pec. | Spe. | Tom. | Vea. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. | | | | | | | | | | | | | | |
| Oct. 28... | L. | M. | 97 | 94 | 94 | 112 | 84 | 102 | 99 | 93 | 91 | 99 | 97 | 97 |
| | | S.D. | 6.1 | 4.5 | 8.1 | 11.5 | 5.0 | 7.8 | 7.9 | 9.1 | 5.9 | 7.9 | 10.1 | 3.2 |
| | | C. | 6.3 | 4.8 | 8.6 | 10.3 | 5.9 | 7.6 | 8.0 | 9.8 | 6.5 | 8.0 | 10.4 | 3.3 |
| | R. | M. | 96 | 88 | 76 | 100 | 90 | 103 | 86 | 88 | 96 | 114 | 95 | 89 |
| | | S.D. | 5.8 | 4.1 | 5.8 | 6.1 | 4.2 | 11.3 | 8.4 | 4.2 | 4.8 | 9.9 | 6.1 | 6.5 |
| | | C. | 6.0 | 4.7 | 7.6 | 6.1 | 4.7 | 11.0 | 9.8 | 4.8 | 5.0 | 8.7 | 6.4 | 7.3 |
| Nov. 25... | L. | M. | 96 | 88 | 99 | 114 | 92 | 109 | 97 | 99 | 111 | 124 | 106 | 100 |
| | | S.D. | 7.4 | 5.8 | 11.9 | 10.9 | 6.7 | 6.9 | 8.3 | 8.6 | 11.8 | 15.2 | 12.9 | 8.1 |
| | | C. | 7.7 | 6.6 | 12.0 | 9.6 | 7.3 | 6.3 | 8.6 | 8.7 | 10.6 | 12.3 | 12.2 | 8.1 |
| | R. | M. | 103 | 80 | 80 | 93 | 95 | 98 | 78 | 92 | 92 | 113 | 100 | 90 |
| | | S.D. | 8.4 | 4.9 | 6.1 | 6.4 | 6.2 | 8.4 | 7.4 | 8.1 | 8.5 | 15.0 | 9.5 | 11.1 |
| | | C. | 8.2 | 6.1 | 7.6 | 6.9 | 6.5 | 8.6 | 9.5 | 8.8 | 9.2 | 13.3 | 9.5 | 12.3 |
| Dec. 9... | L. | M. | 107 | 94 | 95 | 108 | 87 | 98 | 101 | 95 | 119 | 128 | 107 | 101 |
| | | S.D. | 9.9 | 4.5 | 11.3 | 14.4 | 6.9 | 11.6 | 8.4 | 9.6 | 15.7 | 14.8 | 10.3 | 10.0 |
| | | C. | 9.3 | 4.8 | 11.9 | 13.3 | 7.9 | 11.8 | 8.3 | 10.1 | 13.2 | 11.6 | 9.6 | 9.9 |
| | R. | M. | 104 | 84 | 77 | 95 | 92 | 98 | 83 | 84 | 105 | 125 | 106 | 87 |
| | | S.D. | 8.6 | 5.4 | 5.9 | 5.8 | 8.2 | 5.8 | 7.4 | 4.2 | 18.9 | 17.0 | 17.4 | 5.6 |
| | | C. | 8.3 | 6.4 | 7.7 | 6.1 | 8.9 | 5.9 | 8.9 | 5.0 | 18.0 | 13.6 | 16.4 | 6.4 |
| 1918. | | | | | | | | | | | | | | |
| Jan. 13... | L. | M. | 104 | 87 | 93 | 120 | 92 | 107 | 106 | 96 | 114 | ..... | 98 | 108 |
| | | S.D. | 8.8 | 6.8 | 11.0 | 14.9 | 9.5 | 8.8 | 11.3 | 8.4 | 12.5 | ..... | 11.5 | 9.5 |
| | | C. | 8.5 | 7.8 | 11.8 | 12.4 | 10.3 | 8.2 | 10.7 | 8.8 | 11.0 | ..... | 11.7 | 8.8 |
| | R. | M. | 101 | 79 | 75 | 94 | 99 | 102 | 85 | 86 | 102 | ..... | 91 | 91 |
| | | S.D. | 8.1 | 3.0 | 5.8 | 5.5 | 10.5 | 12.3 | 10.7 | 7.4 | 11.7 | ..... | 10.1 | 6.8 |
| | | C. | 8.0 | 3.8 | 7.7 | 5.9 | 10.6 | 12.1 | 12.6 | 8.6 | 11.5 | ..... | 11.1 | 7.5 |
| Jan. 27... | L. | M. | 106 | 87 | 100 | 131 | 98 | 107 | 109 | 101 | 107 | ..... | 105 | 104 |
| | | S.D. | 9.6 | 7.7 | 14.0 | 16.5 | 9.1 | 11.0 | 10.7 | 8.1 | 9.2 | ..... | 14.3 | 9.6 |
| | | C. | 9.1 | 8.9 | 14.0 | 12.6 | 9.3 | 10.3 | 9.8 | 8.0 | 8.6 | ..... | 13.6 | 9.2 |
| | R. | M. | 106 | 81 | 75 | 102 | 101 | 96 | 87 | 88 | 99 | ..... | 98 | 85 |
| | | S.D. | 8.1 | 4.8 | 6.6 | 9.3 | 9.8 | 5.7 | 8.8 | 7.7 | 7.4 | ..... | 7.6 | 8.1 |
| | | C. | 7.6 | 5.9 | 8.8 | 9.1 | 9.7 | 5.9 | 10.1 | 8.8 | 7.5 | ..... | 7.8 | 9.5 |
| Low-diet av...... | L. | M. | 102.0 | 90.0 | 96.2 | 117.0 | 90.6 | 104.6 | 102.4 | 96.8 | 108.4 | 117.0 | 102.6 | 102.0 |
| | | S.D. | 8.4 | 5.9 | 11.3 | 13.6 | 7.4 | 9.2 | 9.3 | 8.8 | 11.0 | 12.6 | 11.8 | 8.1 |
| | | C. | 8.2 | 6.6 | 11.7 | 11.6 | 8.1 | 8.8 | 9.1 | 9.1 | 10.0 | 10.6 | 11.5 | 7.9 |
| | R. | M. | 102.0 | 82.4 | 76.6 | 96.8 | 95.4 | 99.4 | 83.8 | 87.6 | 98.8 | 117.3 | 98.0 | 88.4 |
| | | S.D. | 7.8 | 4.4 | 6.0 | 6.6 | 7.8 | 8.7 | 8.5 | 6.3 | 10.3 | 14.0 | 10.1 | 7.6 |
| | | C. | 7.6 | 5.4 | 7.9 | 6.8 | 8.1 | 8.7 | 10.2 | 7.2 | 10.2 | 11.9 | 10.2 | 8.6 |

eye-movement records shown with Squad B, November 4, is slightl above 8 per cent as an average for the variability figures of the ind vidual series. Individual subjects show variabilities which range fro 4 per cent with *Lon*, left, to 12.7 per cent with *How*, left.

[1]From a totally different series of experiments we have records on one subject who, wh the records were taken, was very sleepy and his eye movement time for 40° movements is the range of 280 to 300; he started the series of movements at the signal from the operat but the plate shows that he very soon closed his eyes and was asleep.

On the average for the 3 days, November 4, 18, and December 16, the men of Squad B have average eye movement time which, in the case of movements left, ranges from 88.0 to 117.5 σ, *Sne* and *Fis*. The average for all is 96.3 σ, the average variability 8.3 per cent. In the case of movements right the range is from 81.7 to 104.5 σ for *How* and *Fis*, respectively. The average for the 10 subjects usually discussed is 89.3 σ, the variability 8.6 per cent. Thus the members of Squad B show no values which are on the one hand as small, or on the other as large, as the limiting ranges of the group of 1917.

TABLE 181.—*Squad B—Eye movement speed and its variability.*

[L. and R. designate left and right movements, M. and S. D. in σ, and C. in per cent.]

| Date. | Eye. | Speed. | Fis. | Har. | How. | Ham. | McM. | Kim. | Lon. | Mac. | Sch. | Liv. | Sne. | Tho. | Van. | Wil. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. Nov. 4 | L. | M. | 116 | 87 | 86 | 98 | 96 | ..... | 99 | 108 | ..... | 90 | 90 | 93 | 98 | 94 | 95.1 |
| | | S.D. | 9.4 | 9.3 | 7.2 | 7.2 | 7.6 | ..... | 4.0 | 8.4 | ..... | 6.9 | 8.7 | 6.9 | 6.9 | 10.2 | 7.7 |
| | | C. | 8.1 | 10.7 | 8.4 | 7.4 | 7.9 | ..... | 4.0 | 7.8 | ..... | 7.7 | 9.7 | 7.4 | 7.0 | 10.9 | 8.1 |
| | R. | M. | 102 | 85 | 82 | 93 | 97 | ..... | 93 | 87 | ..... | 81 | 82 | 90 | 92 | 89 | 88.9 |
| | | S.D. | 6.5 | 10.7 | 7.9 | 7.4 | 5.6 | ..... | 10.3 | 6.0 | ..... | 6.2 | 4.7 | 6.6 | 7.1 | 8.3 | 7.6 |
| | | C. | 6.4 | 12.6 | 9.6 | 8.0 | 5.8 | ..... | 11.1 | 6.9 | ..... | 7.7 | 5.7 | 7.3 | 7.7 | 9.3 | 8.5 |
| Nov. 18 | L. | M. | 119 | 96 | 90 | 103 | 94 | ..... | 98 | 105 | ..... | 95 | 87 | 108 | 105 | 104 | 100 |
| | | S.D. | 13.2 | 6.8 | 5.3 | 9.7 | 5.8 | ..... | 12.2 | 7.1 | ..... | 8.7 | 7.9 | 5.9 | 7.3 | 12.1 | 8.9 |
| | | C. | 11.1 | 7.1 | 5.9 | 9.4 | 6.2 | ..... | 12.5 | 6.8 | ..... | 9.2 | 9.1 | 5.7 | 7.0 | 11.6 | 8.9 |
| | R. | M. | 107 | 83 | 81 | 99 | 104 | ..... | 89 | 86 | ..... | 85 | 86 | 96 | 98 | 90 | 91.4 |
| | | S.D. | 13.4 | 6.8 | 6.2 | 10.7 | 10.0 | ..... | 8.3 | 4.5 | ..... | 5.0 | 5.7 | 6.7 | 8.4 | 9.8 | 8.1 |
| | | C. | 12.5 | 8.2 | 7.7 | 10.8 | 9.6 | ..... | 9.3 | 5.2 | ..... | 5.9 | 6.6 | 7.0 | 8.6 | 10.3 | 8.7 |
| Dec. 16 | L. | M. | ..... | 86 | 89 | 100 | 103 | ..... | 90 | 99 | ..... | 92 | 87 | 97 | 104 | 98 | 93.7 |
| | | S.D. | ..... | 5.6 | 11.3 | 11.4 | 8.9 | ..... | 9.6 | 10.5 | ..... | 5.6 | 5.2 | 6.4 | 8.7 | 3.7 | 7.5 |
| | | C. | ..... | 6.5 | 12.7 | 11.4 | 8.6 | ..... | 10.7 | 10.6 | ..... | 6.1 | 6.0 | 6.6 | 8.4 | 3.8 | 8.0 |
| | R. | M. | ..... | 82 | 82 | 97 | 105 | ..... | 90 | 83 | ..... | 85 | 82 | 92 | 94 | 85 | 87.7 |
| | | S.D. | ..... | 5.8 | 6.9 | 10.5 | 12.7 | ..... | 10.5 | 3.0 | ..... | 5.6 | 5.2 | 7.2 | 11.8 | 4.7 | 7.6 |
| | | C. | ..... | 7.1 | 8.4 | 10.8 | 12.1 | ..... | 11.7 | 3.6 | ..... | 6.6 | 6.3 | 7.8 | 12.6 | 5.5 | 8.5 |
| Normal av... | L. | M. | 117.5 | 89.7 | 88.3 | 100.3 | 97.7 | ..... | 95.7 | 104.0 | ..... | 92.3 | 88.0 | 97.7 | 102.3 | 96.7 | 96.3 |
| | | S.D. | 11.3 | 7.2 | 7.9 | 9.4 | 7.4 | ..... | 8.6 | 8.7 | ..... | 7.1 | 7.3 | 6.4 | 7.6 | 8.7 | 8.0 |
| | | C. | 9.6 | 8.1 | 9.0 | 9.4 | 7.6 | ..... | 9.1 | 8.4 | ..... | 7.7 | 8.3 | 6.6 | 7.5 | 8.8 | 8.3 |
| | R. | M. | 104.5 | 83.3 | 81.7 | 96.3 | 102.0 | ..... | 90.7 | 85.3 | ..... | 83.7 | 83.3 | 92.7 | 94.7 | 88.0 | 89.3 |
| | | S.D. | 10.0 | 7.8 | 7.0 | 9.5 | 9.4 | ..... | 9.7 | 4.5 | ..... | 5.6 | 5.2 | 6.8 | 9.1 | 7.4 | 7.8 |
| | | C. | 9.5 | 9.3 | 8.6 | 9.9 | 9.2 | ..... | 10.7 | 5.2 | ..... | 6.7 | 6.2 | 7.4 | 9.6 | 8.4 | 8.6 |
| 1918. Jan. 14 | L. | M. | ..... | ..... | 89 | 113 | ..... | 110 | 97 | ..... | 71 | 96 | 85 | 100 | 101 | 107 | 98.5 |
| | | S.D. | ..... | ..... | 7.1 | 10.4 | ..... | 12.0 | 11.0 | ..... | 5.8 | 9.1 | 5.8 | 6.9 | 6.3 | 11.5 | 8.5 |
| | | C. | ..... | ..... | 8.0 | 9.2 | ..... | 10.9 | 11.3 | ..... | 8.2 | 9.5 | 6.8 | 6.9 | 6.2 | 10.7 | 8.6 |
| | R. | M. | ..... | ..... | 85 | 95 | ..... | 85 | 94 | ..... | 77 | 86 | 80 | 95 | 92 | 94 | 90.1 |
| | | S.D. | ..... | ..... | 7.1 | 6.9 | ..... | 5.9 | 10.3 | ..... | 5.7 | 4.0 | 5.1 | 6.0 | 5.8 | 9.5 | 6.8 |
| | | C. | ..... | ..... | 8.4 | 7.3 | ..... | 6.9 | 11.0 | ..... | 7.4 | 4.7 | 6.4 | 6.3 | 6.3 | 10.1 | 7.6 |
| Jan. 20 | L. | M. | 118 | 88 | 91 | 106 | ..... | 110 | 99 | ..... | 76 | 95 | 84 | 98 | 104 | 108 | 99.1 |
| | | S.D. | 11.2 | 8.8 | 10.9 | 10.6 | ..... | 11.9 | 8.9 | ..... | 6.3 | 8.4 | 7.3 | 7.9 | 7.5 | 12.7 | 9.4 |
| | | C. | 9.5 | 10.0 | 12.0 | 10.2 | ..... | 10.8 | 9.0 | ..... | 8.3 | 8.5 | 8.7 | 8.1 | 7.2 | 11.8 | 9.5 |
| | R. | M. | 107 | 83 | 85 | 102 | ..... | 93 | 94 | ..... | 72 | 83 | 82 | 95 | 92 | 94 | 91.7 |
| | | S.D. | 7.9 | 7.8 | 7.1 | 9.8 | ..... | 8.0 | 8.3 | ..... | 5.3 | 8.3 | 5.5 | 7.5 | 7.3 | 11.3 | 8.1 |
| | | C. | 7.4 | 9.4 | 8.4 | 9.6 | ..... | 8.6 | 8.8 | ..... | 7.4 | 10.0 | 6.8 | 7.9 | 7.9 | 12.0 | 8.8 |
| Low-diet av. | L. | M. | 118.0 | 88.0 | 90.0 | 109.5 | ..... | 110.0 | 98.0 | ..... | 73.5 | 95.5 | 84.5 | 99.0 | 102.5 | 107.5 | 98.8 |
| | | S.D. | 11.2 | 8.8 | 9.0 | 10.6 | ..... | 12.0 | 10.0 | ..... | 6.1 | 8.5 | 6.6 | 7.4 | 6.9 | 12.1 | 9.0 |
| | | C. | 9.5 | 10.0 | 10.0 | 9.7 | ..... | 10.9 | 10.2 | ..... | 8.3 | 9.2 | 7.8 | 7.5 | 6.7 | 11.3 | 9.1 |
| | R. | M. | 107.0 | 83.0 | 85.0 | 98.5 | ..... | 89.0 | 94.0 | ..... | 74.5 | 84.5 | 81.0 | 95.0 | 92.0 | 94.0 | 90.9 |
| | | S.D. | 7.9 | 7.8 | 7.1 | 8.4 | ..... | 7.0 | 9.3 | ..... | 5.5 | 6.2 | 5.3 | 6.8 | 6.6 | 10.4 | 7.5 |
| | | C. | 7.4 | 9.4 | 8.4 | 8.5 | ..... | 7.5 | 9.9 | ..... | 7.4 | 7.4 | 6.6 | 7.1 | 7.1 | [illegible] | [illegible] |

Squad B had two dates with the eye movement measurements, January 14 and 20, under conditions of reduced diet. These results are averaged at the bottom of table 181. The average for $L$ is 98.8 $\sigma$, which can be compared with the 96.3 $\sigma$ of the normal. The average for $R$ is 90.9 $\sigma$ as against 89.3 $\sigma$. The indications are, therefore, that the eye movements were slightly slower during the period of the reduced diet.

Table 180 shows the data of eye-movement speed for Squad A. At their first session, October 28, 3 weeks after the beginning of the reduced diet, the average speed for left movement was 96.6 $\sigma$ and variability 7.3 per cent. The average speed for right movement was 93.1 $\sigma$ with variability 6.6 per cent. Individual subjects ranged, left, from 84 to 112 $\sigma$ for *Gul* and *Gar*, and for right from 76 to 114 $\sigma$ for *Kon* and *Spe*.[1] In the variability for left movements, the men ranged from 3.3 to 10.4 for *Vea* and *Tom*. For right movements they ranged from 4.7 to 11.0, *Can* and *Gul* and *Mon*.

The individuals of Squad A have averages for the dates October 28, November 25, December 9, January 13, and January 27.[2] The averages for all of these dates are shown at the bottom of table 180. The total average for the 10 men is for left movements, 101.6 $\sigma$, for right, 93.3 $\sigma$. The variability is 9.1 and 8.3 per cent, respectively, for left and right. Thus all of the averages for eye movements shown by members of Squad A fall within the range found for the normal series of 1917.

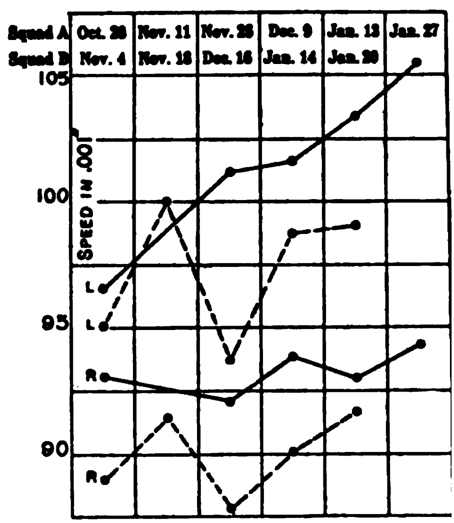



FIG. 117.—Speed of the eye movements.

*L* and *R* designate movements to the left and to the right. Solid lines represent Squad A, broken lines Squad B.

The influence of the low-diet condition upon this muscle coordination process may be judged better from the data presented in diagrammatic form in figures 117 and 118. In figure 117 the solid lines represent, as in other curves, the data of Squad A. The two curves in each case are designated $L$ and $R$, for left and right. The speed of the movements left shows a definite and regular lengthening with the

[1] The record of 114 $\sigma$ for *Spe* is associated with an error in the procedure in that the left eye was not covered.

[2] The measurement was also used on November 11, but owing to a difficulty with the apparatus the records were nearly all failures.

progress of the experiment. The time requirement gradually increased from about 97 to 106 $\sigma$, a lengthening of 9.3 per cent. It is true that not all of the subjects of Squad A demonstrate this same change. For example, *Can* has values for the left movements for the different dates as follows: 94, 88, 94, 87, and 87 $\sigma$. On the other hand, we may point out *Gar*, whose values for left are 112, 114, 108, 120 and 131 $\sigma$. With the majority of subjects the length of time tends to increase from October 28 until January 27. The eye movements to the right (see solid line for *R* in fig. 117) show almost no progressive change during the low-diet period. This difference between the right movements and the left movements is a surprising fact, but it absolutely agrees with results previously found in this Laboratory.[1] It was found n the investigation with small amounts of alcohol that with the eye movements the alcohol effect was predominantly upon movements to the left in the ratio of 10 to 4.

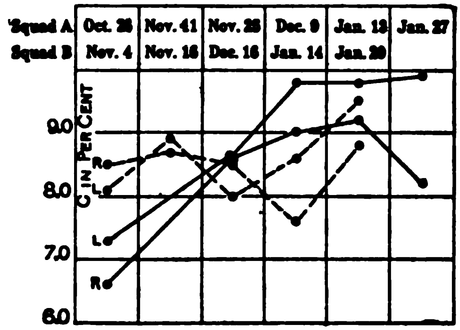



Fig. 118.—Variability in the speed of the eye movements.

*L* and *R* designate movements to the left and to the right. Solid lines represent Squad A, broken lines Squad B.

Squad B (see the broken line in fig. 117) demonstrates a wide range of variation between their three normals, November 4, November 18, and December 16. Some uncontrolled influence was operating on November 18, but definite information is lacking. It is very apparent that it influenced the movements to the left more strongly than it did those to the right. The average results for the low-diet dates January 14 and 20 show slower speed than the two normal dates, November 4 and December 16. This is particularly true with the movements to the left, thus agreeing with the results for Squad A. Including in the average the aberrant values of November 18 with these normals for November 4 and December 16, it is still true, as shown in table 181, that the average for the low diet shows slower speed than for normal conditions. The results of the two squads therefore substantiate each other in the direction of the low-diet effect on this neuro-muscular process of eye movements. It appears with both groups of men that the muscle coordination of moving the right eye from a point at the right of the field of vision to a point at the left is more delicate and easily disturbed than the complementary coordination for movements of the same eye from a point at the left through 40° to the right.

[1]Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 163, table 26.

The average variability of the two squads for right and left mov ment is presented in figure 118. Squad A appears to show a gradu increase in the variability, which is high for December 9, January 1 and January 27, except that on the latter date the variability for was decreased. In the case of Squad B the variability is larger November 18 than for the other two normal dates. It also rises the point of January 20 during the low-diet experiment. Squad shows no considerable increase in the variability at their first low-di date. This would appear to agree, also, with Squad A. Since t first date for Squad A, October 28, was during the early part of t low-diet period and showed a variability of nearly 7 per cent, we jud this to be about as small as could reasonably be expected.

Associated with the prolonged reduced diet the eye movements sho a slower speed in the case of Squad A amounting in the extreme to a proximately 5 per cent for averages of movements right and left. Wi this there is also an increase in the variability. The results for th measurement found on Squad B confirm the direction of those observ with Squad A.

### (15) SPEED OF THE FINGER MOVEMENTS.

In this muscle coordination test the number of complete oscillatio of the finger which the average individual can perform in 10 secon ranges between 55 and 75. In the normal series of 1917 finger-mov ment records were obtained on 61 of the men, the records were phot graphic, and were extended for only 8 seconds. The average for t group of 61 normal men in the 1917 series on whom such records we taken was 52.1 complete oscillations in 8 seconds. The records ma in the evening for Squads A and B are given in tables 182 and 18 The average performance on the normal date (September 29) for Squ A was 68.7 oscillations; the average for the first experiment with Squ B was 66.0 oscillations. The foregoing values are for records seconds long. If we count only the first 8 seconds so as to make the comparable with the normal series of 1917, the initial normal resul are 55.7 and 53.7 oscillations for A and B, respectively. Thus the tw groups of men agree fairly well with each other and with the larg normal group. With Squad A the individual normal averages ran from 52.3 oscillations for *Tom* to 84.6 oscillations for *Gul*. This la figure is unusually high. *Gul* has previously been noted as a rath short, extremely intense individual. With Squad B the range for t first experiment for the individual subjects is smaller, being from 58 for *How* to 72.5 for *Wil*. The members of A show individual averag exclusive of the first (normal) experiment, which range from 56.5 osc lations for *Moy* to 77.5 oscillations for *Gar*. The average for the subjects for the nine evening experiments is 65.1 oscillations. Squa B show individual averages for their five normal evening experimen which range from 58.6 (*How*) to 75.2 (*Van*), with a total average

65.6 oscillations. For the three evening experiments during the reduced diet period the average is 62.7 oscillations, a reduction from the normal average of 2.9 oscillations, which corresponds to 4.4 per cent. The difference between the normal of Squad A and the average for their nine low-diet periods is 3.6 oscillations, amounting to 5.2 per cent of the normal.

TABLE 182.—*Squad A—Number of finger movements performed in 10 seconds at evening sessions.*

TABLE 183.—*Squad B—Number of finger movements performed in 10 seconds at evening sessions.*

The course of the changes in these finger-movement records is made clear by figure 119. There are fluctuations, but it is very evident that Squad A on the average for the 10 men did better in their normal experiment than at any other time. The total number of finger movements in 10 seconds rather regularly decreased to December 8. There was some recovery on December 19 and January 12, a conspicuous

fall on January 26 with an evident spurt at the last session on Februa 2. Squad B did not show their highest point until January 5. P vious to this time the fluctuations tended, in general, toward a slig decrease, amounting, between October 6 and December 15, to a lit more than one oscillation. The decrease during the normal peri

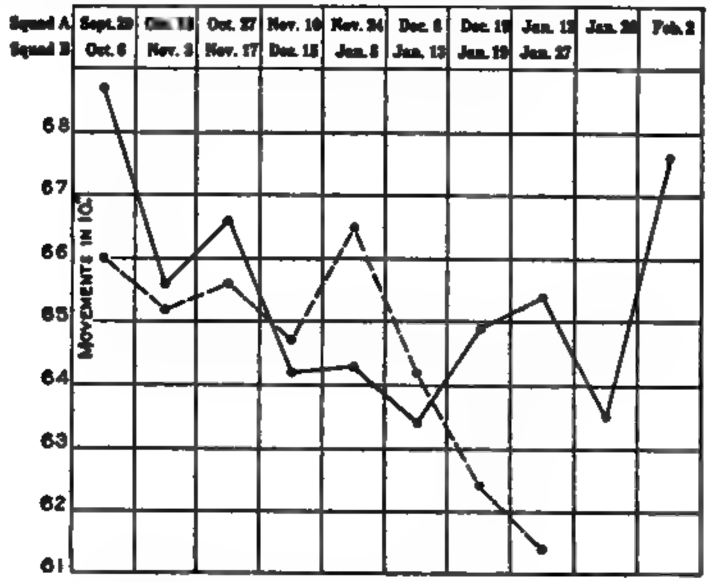



Fig. 119.—Number of finger movements performed in 10 seconds at evening sessions.

Solid lines represent Squad A, broken lines Squad B.

for Squad B is not nearly so prominent as the decrease in the case Squad A. The three experiments of January 13, 19, and 27, whi fall in the food-reduction portion of the experiment for Squad B, sh a definite and progressive decrease in the number of finger moveme

Table 184.—*Squad A—Number of finger movements performed in 10 seconds at morn sessions.*

### (16) EFFICIENCY IN TRAVERSING A RIGHT-ANGLE MAZE.

Two groups of individuals may conceivably show the same initial results in a test or measurement and later, upon repetition of the same task, may demonstrate different degrees of learning ability and rate of improvement. The ability to learn and the conditions which favor or oppose it are of great significance. The maze test was used in this study of the effect of food reduction on men to throw light on this question. It is evident that in repeatedly solving this problem according to directions (see p. 189) the subjects would naturally require shorter and shorter time intervals.

This test, with the same directions and conditions, was used in the normal series of 1917. A group of 67 normal college men, most of them upper classmen or recent college graduates, performed the task three times in succession. The men were carefully observed, and the time from beginning to successful completion of each trial accurately recorded. The classified results for the first two trials are given in table 186. At the initial trial one man did the task in 58 seconds; 23 of the group, that is 34 per cent, completed it in from 101 to 200 seconds; 5 required 600 seconds or more; 2 men failed entirely, giving it up after 18 and 33 minutes, respectively. In the second trial, which was begun about 15 seconds after the first trial was completed, 8 of the men did it in 50 seconds or less, and only one of the 65[1] who completed it required more than 600 seconds. The range in the first trial was from 58 to 1,150 seconds; for the second trial, it was from 35 to 637 seconds; the latter value is from the same individual whose first trial

TABLE 186.—*Distribution of men in normal series of 1917 according to number of seconds required to complete the maze test.*

| Ranges. | 50 or less. | 51 to 75. | 76 to 100. | 101 to 200. | 201 to 300. | 301 to 400. | 401 to 500. | 501 to 600. | 601 or more. |
|---|---|---|---|---|---|---|---|---|---|
| First trial...... | 0 | 1 | 11 | 23 | 12 | 7 | 3 | 3 | 5 |
| Second trial.... | 8 | 15 | 17 | 18 | 3 | 2 | 1 | 0 | 1 |

required the 1,150 seconds. The man who did best in the first trial had values for the three tests as follows: 58, 42, and 76 seconds. In the third trial he became careless and overconfident and lost speed. The individual who showed the best record in the second trial had values for the three trials as follows: 87, 35 and 19 seconds. Some of the other subjects showed very rapid performance with consistent improvement; for example, No. 1, with records of 76, 50, and 45

[1]There was no second trial for the men who are noted as failing in the first. Of course literally these men tried many times, *i. e.*, they made many fresh starts, but always got hopelessly lost through their failure to follow the directions carefully. The third trial followed the second trial after a short intermission, but for one reason or another six of the aviation candidates did not do the task a third time and these data have not been tabulated in table 186. The men in the low-diet research made only one trial to completion on each evening.

SECOND [illegible]

[illegible]

[illegible]

[illegible] SECOND [illegible] SECOND [illegible]

did 12 of the aviators at their first attempt. (See table 186.) Squad B, table 188, in their first trial had approximately the same range as Squad A, that is, from 128 to 526 seconds. One man, *How*, after 1,410 seconds, was unable to complete the test and there was no time for further trial. The average for the initial test of Squad B on October 6, excluding *How*, who did not succeed, and *Mac*,[1] is 208 seconds, that is, somewhat lower than what would normally be expected.

TABLE 188.—*Squad B—Efficiency in performing the maze test.*
[Time in seconds.]

| Date. | Statement of score. | Fis. | Har. | How. | Ham. | McM. | Kim. | Lon. | Mac. | Sch. | Liv. | Sne. | Tho. | Van. | Wil. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. Oct. 6 | Time | 204 | 134 | [2]1410+ | 450 | ..... | ..... | 128 | 252 | ..... | 165 | 131 | 180 | 526 | 157 |
| | Starts | ([3]) | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ... |
| Nov. 3 | Time | 272 | 99 | 770 | 191 | 976 | ..... | 359 | 753 | ..... | 211 | 143 | 645 | 130 | 269 |
| | Starts | 2 | 1 | 7 | 2 | 10 | ..... | 3 | 4 | ..... | 2 | 1 | 4 | 1 | 3 |
| Nov. 17 | Time | 200 | 244 | 248 | 288 | 380 | ..... | 106 | 500 | ..... | 66 | 81 | 207 | 189 | 264 |
| | Starts | 1 | 2 | 2 | 3 | 3 | ..... | 1 | 3 | ..... | 1 | 1 | 1 | 1 | 3 |
| Dec. 15 | Time | ..... | 182 | 397 | 141 | 488 | ..... | 197 | 280 | ..... | 46 | 71 | 92 | 185 | 68 |
| | Starts | ..... | 1 | 5 | 2 | 5 | ..... | 2 | 1 | ..... | 1 | 1 | 1 | 1 | 1 |
| Jan. 5 | Time | 87 | 51 | 119 | 49 | 220 | ..... | ..... | ..... | 590 | 60 | 116 | 93 | 88 | 61 |
| | Starts | 1 | 1 | 2 | 1 | 3 | ..... | ..... | ..... | 4 | 1 | 2 | 1 | 1 | 1 |
| Normal av... | Time | 191 | 142 | 384 | 224 | 516 | ..... | 198 | 446 | 594 | 110 | 108 | 243 | 224 | 164 |
| | Starts | 1.3 | 1.3 | 4.0 | 2.0 | 5.3 | ..... | 2.0 | 2.7 | 4 | 1.3 | 1.3 | 1.8 | 1 | 2 |
| Jan. 13 | Time | 103 | 42 | 43 | 217 | ..... | 374 | 70 | ..... | 164 | 77 | 56 | 66 | 69 | 51 |
| | Starts | 1 | 1 | 1 | 3 | ..... | 3 | 1 | ..... | 1 | 1 | 1 | 1 | 1 | 1 |
| Jan. 19 | Time | 71 | 41 | 61 | 44 | ..... | 75 | 37 | ..... | 200 | 37 | 50 | 58 | 281 | 47 |
| | Starts | 1 | 1 | 1 | 1 | ..... | 1 | 1 | ..... | 1 | 1 | 1 | 1 | 4 | 1 |
| Jan. 27 | Time | 61 | 39 | 51 | 41 | ..... | 46 | 40 | ..... | 163 | 29 | 50 | 50 | 105 | 36 |
| | Starts | 1 | 1 | 1 | 1 | ..... | 1 | 1 | ..... | 1 | 1 | 1 | 1 | 2 | 1 |
| Low-diet av. | Time | 78 | 41 | 52 | 101 | ..... | 165 | 49 | ..... | 176 | 48 | 52 | 58 | 152 | 45 |
| | Starts | 1 | 1 | 1 | 1.7 | ..... | 1.7 | 1 | ..... | 1 | 1 | 1 | 1 | 2.3 | 1 |

[1] These averages do not include *McM*, *Kim*, *Mac*, and *Sch*.
[2] Not in the average.
[3] Number of starts not recorded on first day.

It is unnecessary to discuss the individual values. Aside from some irregularities nearly all the subjects show a rather consistent reduction in time required for the task from experiment to experiment. In the nature of the case, it could not be expected that the normal average and the low-diet average of Squad B would be directly comparable. The average values for both squads are plotted in figure 122. It is noteworthy that the two curves are nearly at the same level and follow the same general course; they may reasonably be regarded as normal practice curves. Squad B was somewhat handicapped by the longer interval between their first and second experiments, that is,

[1] The latter is excluded because his records are not complete for the food reduction period.

from October 6 to November 3, and there is a marked decline on the latter date. Inspection of table 188 will show that 7 of the men increased the time for performing the task. They seem to have approached the problem in an overconfident attitude, and not to have paid careful attention to the directions. Five of these men who required a longer time at the second trial became confused; these subjects had to make three or four beginnings before they completed the task.[1] Another cause for the depression in the curve of Squad B on November 3 is that on this date *How* was included, but he was not included in the average for October 6 as he failed to complete the task. His score for November 3 is largest of all, being 770 seconds. Beyond this point,

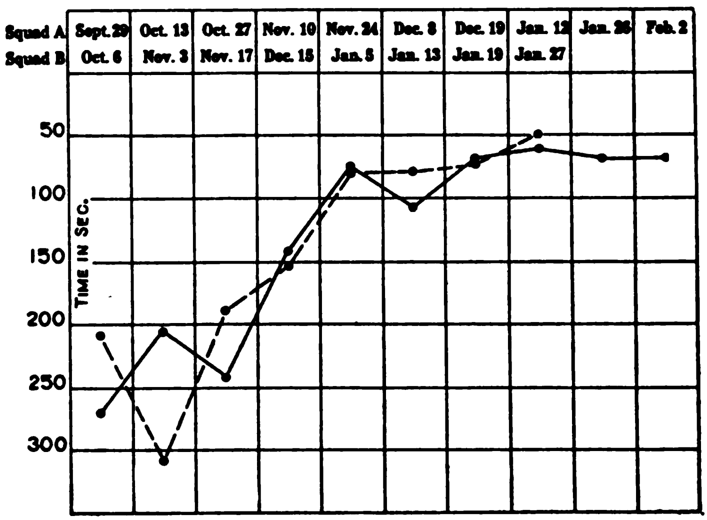



FIG. 122.—Average time required to complete the maze-tracing task. Solid lines represent Squad A, broken lines Squad B.

Squad B continued to improve and reached a level on January 5, from which they improved very slowly on the three food-reduction dates.

The curve for Squad A is depressed on October 27. This is not shown by the individual performance of all the group, but appears to be due largely to the poor and irregular performance of *Gar* and *Vea;* the former became confused twice and was obliged to begin again, with the result that the time required (1,110 seconds) is the longest in table 187 for the 9 men whose records are averaged. There is also a depression in the curve on December 8. This was also due to the irregular work of *Vea* and *Gar*, and to some extent of *Tom*. The averages for the last

[1]No record was kept of the number of beginnings required on the first evening. This record for later experiments is included in the table, as it illuminates the time record, indicating in the case of a long time whether they moved very slowly and carefully or carelessly.

order of size. Scores were allowed as follows: All correct, 18 points; one erasure, 15 points; two or more erasures, 12 points; two transposed, 6 points; more than two transposed or uncorrected, 0. Task No. 4, 10 names were to be numbered in alphabetical order. The scores allowed were: All correct, 18; 1 erasure, 15; 2 or more erasures, 12; 2 names transposed, 6; more than 2 transposed, 0. Task No. 5 was the copying of 6 nine-place numbers. If all were copied correctly the score was 10; with 1 digit wrong or 2 transposed, 5; 2 digits wrong or 3 transposed, 0. In task No. 6, in which the subject was required to describe the location of a certain item and in the second part to locate certain items according to direction, a perfect record was scored 18 points; 1 mistake, 12 points; 2 mistakes, 6 points; 3 or more mistakes, 0 credit.

TABLE 189.—*Squad A—Accuracy in performing the clerical tasks.*

[Values given for total time in seconds, total number of points made, and number of points per min.]

| Date. | Statement of score. | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pes. | Pec. | Spe. | Tom. | Ves. | Fre. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. | | | | | | | | | | | | | | | |
| Sept. 29 | Time..... | 490 | 876 | 595 | 762 | 546 | 721 | 742 | 604 | 1027 | 645 | 459 | 628 | 428 | 686 |
| | Points.... | 100 | 91 | 52 | 73 | 73 | 82 | 55 | 56 | 61 | 73 | 64 | 91 | 82 | 74.6 |
| | P. per min. | 12.3 | 6.2 | 5.3 | 5.8 | 8.0 | 6.8 | 4.5 | 5.6 | 3.6 | 6.8 | 8.4 | 8.7 | 11.5 | 6.99 |
| Oct. 13 | Time..... | 522 | 813 | ..... | 776 | 689 | 476 | 490 | 403 | 967 | 683 | 388 | 554 | 271 | 608 |
| | Points.... | 88 | 67 | ..... | 88 | 88 | 94 | 76 | 64 | 85 | 64 | 82 | 76 | 97 | 80.8 |
| | P. per min. | 10.1 | 4.9 | ..... | 6.8 | 7.7 | 11.9 | 9.3 | 9.5 | 5.3 | 5.6 | 12.7 | 8.2 | 21.5 | 8.64 |
| Oct. 27 | Time..... | 422 | 828 | 548 | 688 | 694 | 1355 | 685 | 407 | 755 | 570 | 437 | 482 | ..... | 675 |
| | Points.... | 85 | 59 | 79 | 91 | 67 | 51 | 76 | 86 | 73 | 76 | 64 | 79 | ..... | 73.1 |
| | P. per min. | 12.1 | 4.3 | 8.7 | 7.9 | 5.8 | 2.3 | 6.7 | 12.6 | 5.8 | 8.0 | 8.8 | 9.8 | ..... | 7.61 |
| Nov. 10 | Time..... | 435 | 525 | 737 | 552 | 400 | 577 | 476 | 424 | 760 | 421 | 395 | 404 | ..... | 495 |
| | Points.... | 79 | 82 | 73 | 94 | 88 | 61 | 88 | 79 | 64 | 74 | 97 | 82 | ..... | 81.4 |
| | P. per min. | 10.9 | 9.4 | 6.0 | 10.2 | 13.2 | 6.3 | 11.1 | 11.2 | 5.1 | 10.5 | 14.7 | 12.2 | ..... | 10.4 |
| Nov. 24 | Time..... | 407 | 732 | 682 | 517 | 363 | 528 | 449 | 417 | 734 | 653 | 412 | 521 | ..... | 508 |
| | Points.... | 91 | 82 | 82 | 100 | 97 | 88 | 88 | 94 | 82 | 80 | 94 | 76 | ..... | 89.2 |
| | P. per min. | 13.4 | 6.7 | 7.2 | 11.6 | 16.0 | 10.0 | 11.8 | 13.5 | 6.7 | 7.4 | 13.7 | 8.8 | ..... | 11.2 |
| Dec. 8 | Time..... | 369 | 422 | 622 | 424 | 357 | 509 | 427 | 369 | 583 | 693 | 313 | 355 | ..... | 413 |
| | Points.... | 100 | 76 | 64 | 100 | 97 | 76 | 91 | 97 | 79 | 67 | 82 | 100 | ..... | 89.8 |
| | P. per min. | 16.3 | 10.8 | 6.2 | 14.2 | 16.3 | 9.0 | 12.8 | 15.8 | 8.1 | 5.8 | 15.7 | 16.9 | ..... | 13.6 |
| Dec. 19 | Time..... | 455 | 525 | 532 | 529 | 361 | 650 | 426 | 436 | 651 | ..... | 355 | 468 | ..... | 486 |
| | Points.... | 91 | 88 | 64 | 94 | 82 | 79 | 76 | 77 | 76 | ..... | 91 | 100 | ..... | 85.4 |
| | P. per min. | 12.0 | 10.1 | 7.2 | 10.7 | 13.6 | 7.3 | 10.7 | 10.6 | 7.0 | ..... | 15.4 | 12.8 | ..... | 11.0 |
| 1918. | | | | | | | | | | | | | | | |
| Jan. 12 | Time..... | 414 | 547 | 578 | 683 | 333 | 430 | 416 | 352 | 669 | ..... | 383 | 421 | ..... | 465 |
| | Points.... | 88 | 70 | 64 | 94 | 81 | 97 | 100 | 94 | 82 | ..... | 94 | 91 | ..... | 89.1 |
| | P. per min. | 12.7 | 7.7 | 6.6 | 8.3 | 14.6 | 13.5 | 14.4 | 16.0 | 7.4 | ..... | 14.7 | 13.0 | ..... | 12.2 |
| Jan. 26 | Time..... | 356 | 434 | 529 | 455 | 379 | 485 | 388 | 381 | 706 | ..... | 481 | 347 | ..... | 441 |
| | Points.... | 94 | 88 | 55 | 91 | 76 | 79 | 92 | 88 | 58 | ..... | 94 | 94 | ..... | 85.4 |
| | P. per min. | 15.8 | 12.2 | 6.2 | 12.0 | 12.0 | 9.8 | 14.2 | 13.9 | 4.9 | ..... | 11.7 | 16.2 | ..... | 12.3 |
| Feb. 2 | Time..... | 377 | 458 | 481 | 424 | 364 | 412 | 370 | 269 | 698 | ..... | 336 | 360 | ..... | 407 |
| | Points.... | 100 | 100 | 91 | 100 | 58 | 97 | 100 | 76 | 78 | ..... | 64 | 91 | ..... | 85.9 |
| | P. per min. | 15.9 | 13.1 | 11.4 | 14.2 | 9.6 | 14.1 | 16.2 | 17.0 | 6.3 | ..... | 11.4 | 15.2 | ..... | 13.3 |
| Low-diet av. | Time..... | 417 | 587 | 589 | 561 | 438 | 602 | 459 | 384 | 725 | 604 | 389 | 435 | ..... | 500 |
| | Points.... | 91 | 79 | 71 | 95 | 82 | 80 | 87 | 84 | 75 | 72 | 85 | 88 | ..... | 83.2 |
| | P. per min. | 13.2 | 8.8 | 7.4 | 10.7 | 12.1 | 9.4 | 11.9 | 13.3 | 6.3 | 7.5 | 13.2 | 12.6 | ..... | 11.1 |

The result for the clerical tests with Squads A and B are given in tables 189 and 190. A subject's performance in filling out the blank is represented in the table by three values: (1), the total time required to fill out the blank to his own satisfaction; (2), the number of points which he received without reference to the time expended in performing the task; (3), the average number of points per minute. For illustration: On September 29 (see table 189) the total

TABLE 190.—*Squad B—Accuracy in performing the clerical tasks.*

[Values given for total time in seconds, total number of points made, and number of points per min.]

| Date. | Statement of score. | Fis. | Har. | How. | Ham. | MoM. | Kim. | Lon. | Mac. | Sch. | Liv. | Sne. | Tho. | Van. | Wil. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. Oct. 6 | Time..... | 892 | 724 | [1] | 823 | ..... | ..... | 963 | 1014 | ..... | 1163 | 873 | 666 | [1] | 785 | 860 |
| | Points.... | 88 | 85 | 82 | 94 | ..... | ..... | 97 | 37 | ..... | 81 | 64 | 94 | 82 | 79 | 84. |
| | P. per min. | 5.9 | 7.0 | [1] | 6.9 | ..... | ..... | 6.0 | 2.2 | ..... | 4.2 | 4.4 | 8.5 | [1] | 6.0 | 6. |
| Nov. 3 | Time..... | 820 | 716 | 607 | 622 | 646 | ..... | 588 | 632 | ..... | 805 | 601 | 613 | 576 | 745 | 669 |
| | Points.... | 82 | 85 | 70 | 91 | 67 | ..... | 85 | 70 | ..... | 82 | 100 | 85 | 94 | 56 | 83. |
| | P. per min. | 6.0 | 7.1 | 6.9 | 8.8 | 6.2 | ..... | 8.7 | 6.6 | ..... | 11.1 | 10.0 | 8.3 | 9.8 | 4.5 | 8. |
| Nov. 17 | Time..... | 647 | 630 | 399 | 487 | 601 | ..... | 542 | 758 | ..... | 636 | 518 | 535 | 627 | 730 | 575 |
| | Points.... | 97 | 82 | 76 | 100 | 46 | ..... | 100 | 61 | ..... | 85 | 88 | 100 | 85 | 88 | 90. |
| | P. per min. | 9.0 | 7.8 | 11.4 | 12.3 | 4.6 | ..... | 11.1 | 4.8 | ..... | 8.0 | 10.2 | 11.2 | 8.1 | 7.2 | 9. |
| Dec. 15 | Time..... | [2] | 464 | 441 | 529 | 668 | ..... | 490 | 677 | ..... | 584 | 469 | 520 | 504 | 515 | 502 |
| | Points.... | [2] | 94 | 91 | 91 | 67 | ..... | 88 | 76 | ..... | 91 | 94 | 100 | 76 | 88 | 90. |
| | P. per min. | [2] | 12.2 | 12.4 | 10.3 | 6.0 | ..... | 10.8 | 6.7 | ..... | 9.4 | 12.0 | 11.5 | 9.1 | 10.1 | 10. |
| 1918. Jan. 5 | Time..... | 710 | 718 | 418 | 491 | 689 | 1152 | [2] | ..... | 1548 | 662 | 484 | 576 | 497 | 854 | 600 |
| | Points.... | 79 | 79 | 64 | 97 | 60 | 31 | [2] | ..... | 28 | 91 | 94 | 94 | 85 | 100 | 87. |
| | P. per min. | 6.7 | 6.6 | 9.2 | 11.8 | 5.2 | 1.6 | [2] | ..... | 1.1 | 8.3 | 11.6 | 9.8 | 10.3 | 7.0 | 9. |
| Normal av. | Time..... | 767 | 650 | 466 | 590 | 651 | 1152 | 646 | 770 | 1548 | 770 | 589 | 582 | 551 | 726 | 841 |
| | Points.... | 87 | 85 | 77 | 95 | 60 | 31 | 93 | 61 | 28 | 86 | 88 | 95 | 84 | 82 | 87. |
| | P. per min. | 6.9 | 8.1 | 10.0 | 10.0 | 5.5 | 1.6 | 9.2 | 5.1 | 1.1 | 8.2 | 9.7 | 9.9 | 9.3 | 7.0 | 8. |
| Jan. 13 | Time..... | 543 | 412 | 424 | 455 | ..... | 822 | 572 | ..... | 1206 | 747 | 499 | 478 | 456 | 789 | 538 |
| | Points.... | 91 | 94 | 67 | 100 | ..... | 64 | 74 | ..... | 49 | 88 | 97 | 91 | 91 | 76 | 86. |
| | P. per min. | 10.1 | 13.7 | 9.5 | 13.2 | ..... | 4.7 | 7.8 | ..... | 2.4 | 7.1 | 11.7 | 11.4 | 12.0 | 5.8 | 10. |
| Jan. 19 | Time..... | 535 | 452 | 996 | 415 | ..... | 470 | 503 | ..... | 1137 | 556 | 519 | 452 | 397 | 530 | 536 |
| | Points.... | 97 | 82 | 71 | 100 | ..... | 64 | 88 | ..... | 37 | 100 | 74 | 100 | 85 | 85 | 88. |
| | P. per min. | 10.9 | 10.9 | 4.3 | 14.5 | ..... | 8.2 | 10.5 | ..... | 2.0 | 10.8 | 8.6 | 13.3 | 12.8 | 9.6 | 10. |
| Jan. 27 | Time..... | 516 | 471 | 427 | 430 | ..... | 872 | 561 | ..... | 902 | 653 | 410 | 375 | 375 | 562 | 478 |
| | Points.... | 100 | 94 | 70 | 94 | ..... | 56 | 91 | ..... | 40 | 85 | 88 | 95 | 76 | 79 | 87. |
| | P. per min. | 11.6 | 12.0 | 9.8 | 13.1 | ..... | 3.9 | 9.7 | ..... | 2.7 | 7.8 | 12.9 | 15.2 | 12.2 | 8.4 | 11. |
| Low-diet av. | Time..... | 531 | 445 | 616 | 433 | ..... | 721 | 545 | ..... | 1082 | 652 | 476 | 435 | 409 | 627 | 517 |
| | Points.... | 96 | 90 | 69 | 98 | ..... | 61 | 84 | ..... | 42 | 91 | 86 | 95 | 84 | 80 | 87. |
| | P. per min. | 10.9 | 12.2 | 7.9 | 13.6 | ..... | 5.6 | 9.3 | ..... | 2.4 | 8.6 | 11.1 | 13.3 | 12.3 | 7.9 | 10. |

[1]No time record secured through mistake. [2]Subject absent because of illness.

time required to fill out the blank ranged from 428 to 1,027 seconds (see *Fre* and *Pec*); the average for the 10 subjects was 686 seconds. The total number of points made ranged from 52 to 100 (see *Kon* and *Bro*); the average for the 10 men is 74.6. The average number of points per minute, which is a combination result for time and accuracy, ranges from 3.6 to 12.3 (*Pec* and *Bro*), with an average of 6.99. *Bro* made a particularly good showing; he completed the blank in a comparatively

experiments. It must be noted, moreover, that in the case of Squad B, the two experiments were separated by 4 weeks instead of 2 weeks, as with A. The depression on October 27 is caused in part by the poor records of *Mon* for time and for accuracy. (See table 189, which shows *Mon's* records on this date were for time, 1,355 seconds, total number of points, 51, and points per minute, 2.3.) If this subject were omitted from the average, the figure would be 8.2 points per minute, which would be much more nearly in line with the value shown for October 13, but slightly lower. Improvement is very rapid in the next three sessions, reaching its maximum on December 8. This maximum is

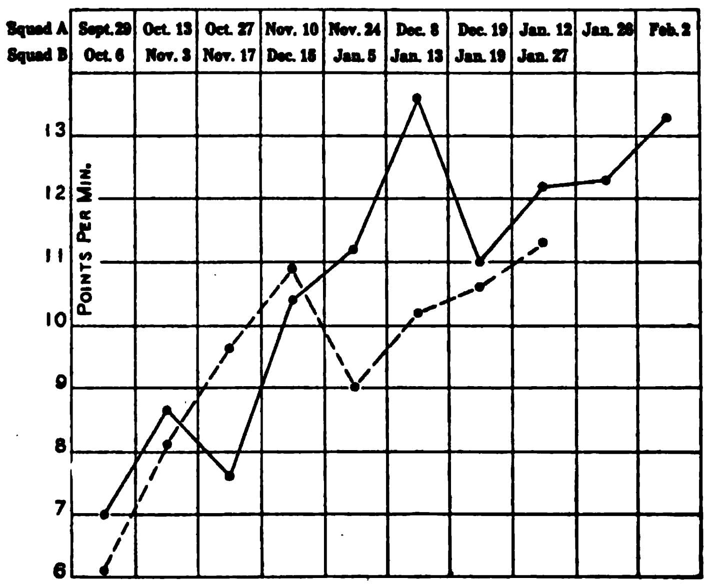



FIG. 123.—Accuracy in performing the clerical tasks.

Solid lines represent Squad A, broken lines Squad B.

largely due, perhaps, to the fortunate circumstance that on that date three of the subjects, *Bro*, *Gar*, and *Vea*, chanced to have perfect records, with the result that their points per minute were in each case the highest they had made at any time in the experiments. Giving their records in order as named, they were 16.3, 14.2, and 16.9 points per minute. The marked depression on December 19 can not be associated with any particular dietetic change, for the men were fairly comfortable at this period of the experiment, as is clearly indicated by their introspections recorded in other sections of this report. The improvement was continued on January 12, 26, and February 2, although not on the high level of December 8. The results, as with several other of our measurements, are complicated. They indicate that Squad B during the three weeks of low diet, and Squad A during the first four weeks of low diet, improved but slowly in their efficiency in the clerical tests.

diet conditions than would, according to our other standards, be expected from these men. These changes in performance and in practice, *i. e.*, learning with successive performances, are most prominent at those periods when the subjects are actually losing weight. The changes, even at these times, are not what could be considered as at all pathological. Just as the weights of the subjects, when they had reached their low level, were still within what are commonly considered by actuarial authorities to be normal limits, so the changes found in the neuro-muscular processes usually seem no larger than the normal range of results for supposedly normal men would permit. It is difficult to estimate how much of a decrement may take place, for example, in the muscle coordinations of a subject, and still not seriously interfere with his usual activities. Theoretically, for competitive, high-grade work, no decrement should be permitted, and therefore no conditions allowed which will operate in the direction of such a decrement. Practically, and under urgent circumstances, an individual may adjust himself to a rather wide range of neuro-muscular changes accompanied by varying conditions or degrees of physiological and psychological comfort and well being and at the same time do his usual work in a way which to others, at least, is not sensibly inferior.

## REDUCED DIET AND SEX EXPRESSION.

Prolonged reduced diet with resulting change to a lower nutritional level might conceivably have some important sociological bearings. It might be asked, for example, if there were under these circumstances any change in the sex interest and desires. Under ordinary conditions trustworthy introspective statements on this problem would be exceedingly difficult to obtain. This is obviously due in large part to the prudishness of our education in regard to sex matters. The ordinary individual is not willing to reveal the facts of his own sex life and finds difficulty in taking an objective attitude in reviewing them. If asked direct questions, many a man would take the attitude that he was insulted and would either refuse the information or evade the truth.

It is important to emphasize the difficulties which usually surround the collection of trustworthy sex data, for it so happens that they contrast sharply with those which were fortunately present in our research. The attitude of the Young Men's Christian Association on knowledge of sex is well known. No other organized group of men has treated the subject in a more straightforward and frank manner. Both in the schools over which they have control and in their public service for men in clubs and gymnasiums, they have labored to establish a sane view of these things and to place private and social hygiene on a sure footing. At the International Y. M. C. A. College at Springfield, especially, it has been recognized that each secretary and physical director must have a sound and wholesome attitude regarding these

sex is closely associated with metabolism and is probably more or less dependent on the metabolic level. These investigators have shown that by modifying one they may modify the other. It is commonly believed that the sex instinct is stronger in men than it is in women. The large amount of metabolism data from this laboratory and other institutions has proved that the metabolism of men is higher than that of women. It is not, therefore, illogical to believe that a lowered metabolism in men may reduce or even obliterate sex interest.

## PHYSICAL ACTIVITY AND ENDURANCE.

The important relationship between muscular work and total metabolism made it incumbent upon us to obtain all possible information with regard to the relative physical activities of these groups of men and their college mates. The diet was to be reduced by design. If the physical activity were likewise considerably reduced, it is obvious that the diet might still be a maintenance diet without a material alteration in the general condition of the body. While the main criterion was to be a reduction in weight of 10 per cent, which would inevitably take place if the supply were materially less than the demand, it still would definitely disturb the relations of the experiment if the subjects reduced the physical activity appreciably. The men were repeatedly instructed and, indeed, urged to keep their bodily activities as nearly normal as possible. It was impressed upon them that the aim of the experiment was to study the effect of a reduced diet upon the efficiency of a group of men in carrying out the ordinary activities of the collegiate life. If they voluntarily and deliberately reduced these activities at the beginning they would not be fulfilling the prime condition of the experiment and would seriously vitiate the results.

These men were all college students and had the regular college program to carry out. This involved a certain amount of walking to and from classes in the different buildings and to the main dining-hall for the several meals, also the gymnasium work prescribed in certain college courses. Furthermore, as with most college students, walking was a regular form of exercise and recreation outside of the prescribed college work.

One development we did not anticipate was the fact that in many instances the men made special efforts to reduce the weight at the beginning of the experiment. To hasten the loss of fat and thus reach the 10 per cent level quickly, they indulged in unusually strenuous and prolonged exercise. The subjects reasoned that the sooner the desired weight reduction was attained, the sooner they would receive larger amounts of food to hold them at this level. This same increase in physical activity appeared several times throughout the course of the experiment, particularly after the uncontrolled Sundays, the short Thanksgiving recess, and the Christmas vacation.

Two attempts were made to secure quantitative estimates of the daily physical activity of these men. It was believed that at least a rough estimation could be obtained by means of pedometer records. Accordingly, each man was supplied with a pedometer which he wore continuously, and daily readings were recorded. When used for level walking over reasonably smooth roads, and particularly when a measure of the length of step has been obtained in walking over a measured distance, the pedometer gives a very satisfactory record of distance walked. It was recognized at the outset, however, that in using these pedometers these men must record activities other than the simple up-and-down motion of the body incidental to ordinary level walking. Accordingly our pedometer records should be looked upon primarily, not as the summation effect of so many up-and-down motions of the body, but as the summation of a large number of body-motions differing materially at times in intensity, and thereby in energy requirements.

TABLE 191.—*Daily record of walking (pedometer) of Vea during period of reduced diet.*

| Date. | Miles walked. | Date. | Miles walked. | Date. | Miles walked. | Date. | Miles walked. |
|---|---|---|---|---|---|---|---|
| 1917. | | | | | | | |
| Oct. 6– 7 | 8.50 | Nov. 5– 6 | 5.00 | Dec. 5– 6 | 5.25 | Jan. 3– 4 | 10.00 |
| 7– 8 | 8.00 | 6– 7 | 4.00 | 6– 7 | 5.50 | 4– 5 | 11.00 |
| 8– 9 | 6.75 | 7– 8 | 6.00 | 7– 8 | 4.25 | 5– 6 | 9.00 |
| 9–10 | 7.75 | 8– 9 | 6.00 | 8– 9 | 5.00 | 6– 7[2] | 1.00 |
| 10–11 | 6.00 | 9–10 | 7.00 | 9–10 | 8.50 | 7– 8 | 5.50 |
| 11–12 | 6.00 | 10–11 | 5.00 | 10–11 | 4.50 | 8– 9 | 3.25 |
| 12–13 | 8.00 | 11–12 | 4.75 | 11–12 | 7.25 | 9–10 | 4.50 |
| 13–14 | 5.00 | 12–13 | 6.25 | 12–13 | 7.75 | 10–11 | 7.50 |
| 14–15 | 7.00 | 13–14 | 2.25 | 13–14 | 4.50 | 11–12 | 4.75 |
| 15–16 | 6.00 | 14–15 | 6.00 | 14–15 | 6.25 | 12–13 | 5.50 |
| 16–17 | 3.50 | 15–16 | 6.50 | 15–16 | 9.25 | 13–14 | 7.25 |
| 17–18 | 7.00 | 16–17 | 9.00 | 16–17 | 4.25 | 14–15 | 1.50 |
| 18–19 | 4.00 | 17–18 | 4.00 | 17–18 | 5.25 | 15–16 | 10.00 |
| 19–20 | 9.25 | 18–19 | 3.25 | 18–19 | 7.00 | 16–17 | 5.50 |
| 20–21 | 7.25 | 19–20 | 10.25 | 19–20 | 3.75 | 17–18 | 5.50 |
| 21–22 | 6.00 | 20–21 | 7:25 | 20–21[2] | 4.00 | 18–19 | 7.50 |
| 22–23 | 5.00 | 21–22 | 10.00 | 21–22 | 6.00 | 19–20 | 5.25 |
| 23–24 | 5.00 | 22–23 | 5.00 | 22–23 | 11.50 | 20–21 | 5.00 |
| 24–25 | 6.50 | 23–24 | 5.75 | 23–24[3] | ...... | 21–22 | 4.75 |
| 25–26 | 2.50 | 24–25 | 5.00 | 24–25 | 12.50 | 22–23 | 8.00 |
| 26–27 | 8.50 | 25–26 | 3.75 | 25–26 | 7.50 | 23–24 | 4.50 |
| 27–28 | 6.50 | 26–27 | 8.50 | 26–27 | 13.00 | 24–25 | 7.75 |
| 28–29 | 6.00 | 27–28 | 7.25 | 27–28 | 16.00 | 25–26 | 3.50 |
| 29–30 | 7.00 | 28–29 | 10.50 | 28–29 | 17.25 | 26–27 | 7.50 |
| 30–31 | 2.50 | 29–30[1] | 16.50 | 29–30 | 17.00 | 27–28 | 4.00 |
| Oct. 31–Nov. 1 | 8.25 | Nov. 30–Dec. 1 | 16.00 | 30–31 | 8.50 | 28–29 | 4.25 |
| Nov. 1– 2 | 3.50 | Dec. 1– 2 | 13.50 | Dec. 31–Jan. 1 | 30.25 | 29–30 | 7.75 |
| 2– 3 | 8.00 | 2– 3[1] | 10.00 | 1918 | ...... | 30–31 | 4.25 |
| 3– 4 | 9.00 | 3– 4 | 9.25 | Jan. 1– 2 | 12.00 | Jan. 31–Feb. 1 | 4.00 |
| 4– 5 | 4.50 | 4– 5 | 3.25 | 2– 3 | 9.00 | Feb. 1– 2 | 4.50 |

[1]Thanksgiving recess, Nov. 29 to Dec. 2, inclusive; diet uncontrolled during this period.
[2]Christmas recess, Dec 20 to Jan. 6, inclusive; diet uncontrolled during this period.
[3]*Vea* ill Dec. 23–24.

Attention has been called to the fact that the individual records for *Vea* (see table 191), showed no pronounced tendency for a progressive reduction in the total distance walked during the four months of the experiment. This same statement applies to the average record for each subject and for the total average for the group of subjects as shown in table 192. This generalization of itself is justification for considering the pedometer records seriously. The most conspicuous exception is the case of *Moy*, whose record decreases with fair regularity in the first 6 weeks, *i. e.*, the pronounced transitional phase of the experiment, from an initital value of 9.20 for October 6 to 11 to 3.11 for November 15 to 22. The records made during the Thanksgiving recess (November 29 to December 2) and the Christmas recess (December 20 to January 6) are of interest, but not directly comparable with the other records shown in the table, since at these times the men naturally had freedom from college and classroom work and were at liberty to walk about more than usual. With the exception of three subjects, *Moy*, *Pec*, and *Vea*, all of the men show higher records (exclusive of those made in vacation periods) at some time after the first week. With *Spe* the highest record is for the second week, October 11 to 18. Nine of the 12 men—*Bro, Can, Kon, Gar, Gul, Mon, Pea, Tom* and *Vea*—show their highest average records at a date following

TABLE 192.—*Weekly record of walking (pedometer)—Squad A, reduced diet.*
[Average miles per day.]

| Dates. | Bro. | Can. | Kon. | Gar. | Gul. | Mon. | Moy. | Pea. | Pec. | Spe. | Tom. | Vea. | Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1917. | | | | | | | | | | | | | |
| Oct. 6–11...... | 7.80 | 7.50 | [1]6.60 | 4.50 | 11.40 | 5.40 | 9.20 | 9.00 | 14.20 | 8.50 | 6.40 | 7.40 | 8.16 |
| Oct. 11–18...... | 8.57 | 7.43 | [1]6.86 | 3.79 | 10.43 | 4.46 | 6.79 | 8.29 | 12.00 | 10.11 | 7.42 | 6.07 | 7.69 |
| Oct. 18–25...... | 5.79 | 6.36 | [1]5.14 | 4.39 | 10.07 | 4.21 | 5.86 | 7.14 | 6.21 | 6.96 | 5.71 | 6.14 | 6.17 |
| Oct. 25–Nov. 1.. | 6.29 | 7.29 | 4.25 | 3.39 | 9.72 | 4.64 | 4.25 | 7.29 | 5.75 | 6.14 | 5.39 | 5.89 | 5.86 |
| Nov. 1– 8...... | 4.29 | 6.25 | 3.64 | 4.07 | 9.86 | 4.79 | 4.71 | 8.43 | 6.50 | 9.86 | 6.50 | 5.71 | 6.22 |
| Nov. 8–15...... | 5.30 | 6.86 | 4.04 | 5.32 | 8.11 | 3.82 | 3.54 | 7.36 | 5.96 | 9.50 | 7.38 | 5.32 | 6.04 |
| Nov. 15–22...... | 6.68 | 10.64 | 4.39 | 8.00 | 11.88 | 5.14 | 3.11 | 7.93 | 10.17 | 6.00 | 7.64 | 7.18 | 7.40 |
| Nov. 22–29...... | 6.96 | 5.29 | 3.65 | 3.73 | 6.54 | 5.76 | 4.09 | 8.00 | 11.67 | 5.36 | 5.71 | 5.82 | 6.05 |
| Nov. 29–Dec. 6[2].. | 10.00 | 8.25 | 5.03 | 5.68 | 10.40 | 7.89 | 7.82 | 8.07 | 9.65 | 9.64 | 7.93 | 10.54 | 8.41 |
| Dec. 6–13...... | 7.32 | 6.04 | 4.21 | 7.96 | 9.32 | 4.64 | 5.07 | 7.36 | 5.00 | 6.13 | 5.50 | 6.11 | 6.22 |
| Dec. 13–19...... | 9.13 | 6.88 | 4.29 | 6.63 | 8.50 | 5.88 | 6.42 | 10.25 | 9.86 | ..... | 6.35 | 6.08 | 7.30 |
| Dec. 20–Jan. 7[3].. | 3.87 | ..... | ..... | .... | 7.78 | 6.05 | 5.46 | 5.66 | ..... | ..... | .... | 11.07 | 6.65 |
| 1918. | | | | | | | | | | | | | |
| Jan. 7–14...... | 7.46 | 5.54 | ..... | 4.20 | 7.46 | 5.50 | 4.75 | 4.18 | 5.56 | ..... | .... | 5.46 | 5.57 |
| Jan. 14–21...... | 7.36 | 5.39 | 4.11 | 6.79 | 10.93 | 5.39 | 5.89 | 6.71 | 9.54 | ..... | 3.50 | 5.75 | 6.49 |
| Jan. 21–28...... | 6.39 | 6.89 | 5.36 | 5.68 | 7.75 | 6.04 | 5.25 | 6.79 | 7.04 | ..... | 2.96 | 5.71 | 5.99 |
| Jan. 28–Feb. 2.. | 10.95 | 6.85 | 5.55 | 5.69 | 11.30 | 6.06 | 7.05 | 4.94 | 8.35 | ..... | 3.60 | 4.95 | 6.84 |

[1]*Fre* served as subject from Oct. 6 to 25, when his place was filled by *Kon*.
[2]Thanksgiving recess, Nov. 29 to Dec. 2, inclusive.
[3]Christmas recess, Dec. 20 to Jan. 6, inclusive.

November 15. On this date the food reduction had been in force for over 40 days,[1] and the ingestion had actually been somewhat increased for maintenance.

From the total averages for the 12 men, it will be seen that the highest average, 8.41 miles, falls at the time of the Thanksgiving recess when the men were free from college duties and were on an uncontrolled diet. That these conditions made a difference in the activity is certain. There are variations in the total weekly averages, but in general these can not be regarded as large. The extreme range, omitting the Thanksgiving recess, is from 5.57 to 8.16 miles per day per man. The latter figure comes at the beginning of the experiment, when possibly psychological factors and weather conditions would naturally favor a large record. Excluding the Thanksgiving and Christmas recesses, the average values for the entire squad are October, 7.0 miles, November, 6.4 miles, December, 6.8 miles, and January, 6.2 miles per day.

The striking increase in the miles walked by *Vea* during the Christmas vacation, combined with the fact that he was at this time on uncontrolled diet, led us to think that throughout the entire research there might be some close correlation between the actual energy of food taken and the miles walked, *i. e.*, with more food there was more inclination to walk. It was found that not only *Vea* but practically all the members of Squad A apparently showed a correlation between these values in that a somewhat liberal diet was coincidental with a greater amount of walking. That this is a case of direct cause and effect is by no means proved. The more liberal diet was almost invariably associated with absence from college, *i. e.*, the Thanksgiving and Christmas recesses, with more time available for and possibly inclination for walking.

### FACTORS INFLUENCING THE PEDOMETER RECORDS.

No great significance should be attached to the pedometer readings without due consideration of the factors influencing them, as otherwise they might lead to false conclusions. As pointed out earlier, the pedometer actually records the up-and-down motion of the body and is supposed to be used exclusively for indicating the distance walked in horizontal forward progression. As previously stated, from the various activities of the men in these squads, we are certain that the pedometer readings may not be directly considered as so many miles walked, especially when we are attempting to attribute a quantitative energy value to the several readings. In other words, each unit recorded on the pedometer may by no means have the same calorific significance. Thus, in going upstairs, each step requires much more energy than a step in

[1] Four of the subjects, *Kon*, *Mon*, *Moy*, and *Tom*, show their highest walking record in the Thanksgiving recess, and *Vea* his surprisingly high record during the Christmas vacation. As may be seen from his individual records in table 191, on December 31 *Vea* took an unusually long walk. The second highest record for *Vea* was during the Thanksgiving recess.

level walking, and yet it would be recorded as one unit by the pedometer. Indeed, with level walking a marked change in the character of the terrain would alter the calorific value of each pedometer unit. Walking on a smooth and level sidewalk would have one value; walking over slippery ice would have a value which would be the resultant of a shorter step and accompanying increase in the leg tension for balance. These pedometers were worn the entire day. The men were cautioned, when riding in automobiles or trolley cars, to be sure that the motion of the vehicle did not cause registration. These false records, however, probably play very little rôle in the series as a whole. It is perfectly conceivable that the activity indicated by a half hour of wrestling or calisthenic exercise in the gymnasium, with jumps up and down, is not at all comparable to the equivalent number of pedometer units registered while walking, hence, it must be recognized that the pedometer does not differentiate in the character of these various units.

We must further consider the factors contributing to activity in general, as recorded by the pedometer. These may be summed up as follows: First, the novelty or the psychological effect is a stimulus to increased record. This would be expected to appear, if at all, in the first week of wearing the instrument. The further possibility of a psychological effect with the squads expressing itself in a desire to make a better showing at the start than a competitive squad should also be considered. A second factor would be weather conditions. With fair weather, such as that obtaining in early fall, walking would be more pleasant than in bad weather, such as might occur later in the season. During icy conditions there would be less tendency for walking but, as pointed out previously, there would follow a distinct change of gait, and possibly a shortening of step with a consequent more rapid registration of pedometer units. It should likewise be remembered that with this shortened step on an icy walk there would be a greater consumption of energy for walking the same distance. Third, with time available for walking so limited during the busy college year, relaxation and recreation would be first sought in walking, as was clearly shown by the records for the Thanksgiving and Christmas recesses. Fourth, the state of nutrition would also affect the inclination for walking.

As has been pointed out, there is a reasonable relationship between the quantity of walking registered by the pedometers and the net available energy in the diets for corresponding periods of time. And yet on close inspection we can not convince ourselves that this is of special significance, because several other factors must be taken into consideration, such as the psychological factor mentioned above and the time available for walking in the vacations. On the assumption, however, that to walk a horizontal mile requires 60 calories, it is very clear that the differences in miles walked at the different stages

about evenly divided in their make-up between men who were taking the course in physical education and those who were taking the secretarial course. As a matter of fact, Squad A had, excluding *Fre*, 7 men taking the physical course and 5 taking the secretarial course, while with Squad B, 9 were taking the physical course and 3 the secretarial course. Undue prominence, however, should not be given to this classification, for it is by no means sure that the activities of the men taking the physical course were very much, if any, greater than those of the subjects taking the secretarial course.

### COMPARISON OF PEDOMETER RECORDS, SQUAD A, WITH THOSE FOR SQUAD B ON NORMAL DIET.

The normal values obtained for Squad B are recorded in the first line of table 193, with an average of 6.24 miles per day. Comparing this average value, obtained when the subjects were on normal diet, with those obtained with Squad A on reduced diet (see table 192) it can be seen that this is not far from a roughly average figure shown by the latter squad. If anything, it is slightly lower than those obtained when Squad A was at maintenance level, namely, December 13 to 19, and the latter part of January. We believe that this is tolerably good evidence that Squad A was not exercising less, at least so far as the pedometer records are concerned, than the average college student of the undergraduate body. Emphasis should again be laid upon the fact that Squad B was on normal diet, as the men were not put upon reduced rations until January 8. The evidence, therefore, as supplied by the pedometer records, is clearly to the effect that Squad A, after the first two weeks, maintained a level of walking which was perfectly comparable, even when on low diet, to that maintained by Squad B on a normal diet with very much larger energy content.

While the closest attempt to secure quantitative measurements of physical activity by means of pedometers leads to the above findings, yet, in view of the defective nature of the pedometer units, an analysis of the probable physical activities, particularly those other than walking, is essential before the final decision can be made as to whether or not Squad A materially altered their physical activity as compared to that of the average undergraduate in the Y. M. C. A. College.

### PEDOMETER RECORDS FOR SQUAD B WITH REDUCED DIET.

The pedometer records for Squad B are given in table 193, together with the normal values obtained on December 13 to 19. In considering these, it is important to bear in mind that the observations made on Squad B comprise solely those during a transitional period. The average number of miles during the first week of reduced diet is practically uniform with that on normal diet, but the pronounced fall in the subsequent two values is worthy of emphasis and is clearly to be ascribed to the very severe reduction in diet which took place.

TABLE 193.—*Weekly record of walking (pedometer)—Squad B.*
[Average miles per day.]

### ESTIMATES OF VARIOUS FORMS OF PHYSICAL ACTIVITY.

In addition to the pedometer readings, which were objective, we have a number of records which were made by the men in connection with their regular college work and for special purposes. Unusual attention is given at the International Y. M. C. A. College to courses on personal efficiency, and not a few of our men in both squads were members of a class which was called upon to report during a given week the actual number of hours spent in sleeping, at meals, dressing and undressing, in productive labor, and in what might be classified as "waste time." Thus they were more than ordinarily keen observers of their own physical activities.[1] As a result of an inspection of a number of the charts used by the men in these courses, a special form of record was prepared and given to all of the men in Squads A and B, to be filled out practically each day throughout the month of January. On these charts a statement was made as to the nature of the exercise, the general health, and the condition of the bowels. Since both squads were on diet during the month of January, a third volunteer squad of 12 men, selected from the student body, were requested to fill out a similar blank to indicate the general nature of the activities of the undergraduate not undergoing the special dietetic regulations, the prime object of this third set of records being to find if a difference existed between the regular college undergraduate and Squads A and B. Thus we have records for approximately 35 men, covering somewhat more than 2 weeks during the month of January.

It will be remembered that during January Squad B was upon a particularly low diet of about 1,300 or 1,400 net calories. It seemed desirable to note if the men in this squad instinctively lowered their physical activities as a result of the greatly lowered food intake. Consequently these observations are reported in rather extensive detail,

[1]To secure a rough estimate of the amount of time the men spent in activities more intense than walking, they were asked at dinner on the night of September 27, *i. e.*, before restriction in the diet began, to give an estimate of the hours spent per week in walking or more active exercise. These records, here expressed as daily values, are as follows: *Bro*, 3.6 hours; *Can*, 1.7 hours; *Fre*, 3.6 hours; *Gar*, 3.9 hours; *Gul*, 4.7 hours; *Mon*, 5.0 hours; *Moy*, 3.6 hours; *Pea*, 3.6 hours; *Pec*, 3.6 hours; *Spe*, 4.0 hours; *Tom*, 3.6 hours; *Vea*, 3.0 hours. This shows an average of 3.7 hours per day.

since these exercise records supply evidence, first, as to the relative activities of Squads A and B, and second, and perhaps more important, the relative activities between Squads A and B and a group of undergraduates not on restricted diet of any form. The observations on general health and condition of the bowels, which for the most part presented no particular phases, are omitted.

The blank furnished each of the men called for a subdivision of the hours per day spent in lying, sitting, and walking; an effort was made to differentiate the activity further by the inclusion of a record of exercise of greater intensity than walking. The time spent in lying obviously included that spent in bed, together with any other time that was so occupied, and does not necessarily mean the time asleep. The sitting involves sitting in the men's rooms, in class, at meal times, etc.

TABLE 194.—*Exercise records during reduced diet—Squad A.*

| Date. | George A. Brown. | | | | Kenneth B. Canfield. | | | | Everett R. Kontner. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lying. | Sitting. | Walking. | Exercise greater than walking.[1] | Lying. | Sitting. | Walking. | Exercise greater than walking.[2] | Lying. | Sitting. | Walking. | Exercise greater than walking.[3] |
| 1918. | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* |
| Jan. 11 | 8 | 9 | 7 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 12 | 8 | 11 | 5 | ...... | 7 | 13 | 4 | ...... | 8 | 12 | 4 | ...... |
| 13 | 8 | 14 | 2 | ...... | 9 | 11 | 4 | ...... | 8 | 15 | 1 | ...... |
| 14 | 8 | 12 | 2 | 2 | 10 | 11 | 2 | 1 | 8 | 15 | 1 | ...... |
| 15 | 9 | 11 | 2 | 2 | 8 | 10 | 6 | ...... | 9½ | 12½ | 1 | 1 |
| 16 | 7½ | 10½ | 4 | 2 | 7 | 12 | 4 | 1 | 9 | 12 | 3 | ...... |
| 17 | 8½ | 11 | 2 | 2½ | 8 | 13 | 3 | ...... | 8 | 13 | 3 | ...... |
| 18 | 8½ | 10 | 3 | 2½ | 7 | 12 | 4 | 1 | 9 | 12 | 3 | ...... |
| 19 | 8 | 12½ | 3 | ½ | 6 | 17 | 1 | ...... | 8 | 12 | 4 | ...... |
| 20 | 8 | 14 | 2 | ...... | 7 | 15 | 2 | ...... | 9 | 14 | 1 | ...... |
| 21 | 8 | 11½ | 2½ | 2 | 7 | 12 | 4 | 1 | 10 | 13 | 1 | ...... |
| 22 | 8 | 10½ | 2 | 3½ | 8 | 12 | 4 | ...... | 9 | 11 | 4 | ...... |
| 23 | 9 | 9 | 4 | 2 | 7 | 14 | 3 | ...... | 8 | 14 | 2 | ...... |
| 24 | 8 | 10½ | 4 | 1½ | 6 | 16 | 2 | ...... | 8 | 14 | 2 | ...... |
| 25 | 9 | 12 | 2½ | ½ | 8 | 13 | 2 | 1 | 6 | 16 | 2 | ...... |
| 26 | 8 | 12 | 4 | ...... | 9 | 13 | 2 | ...... | 7 | 14 | 3 | ...... |
| 27 | 8 | 14 | 2 | ...... | 8 | 14 | 2 | ...... | 9 | 13 | 2 | ...... |
| 28 | 7½ | 12½ | 2 | 2 | 9 | 12 | 2 | 1 | 8 | 13 | 3 | ...... |
| 29 | 8 | 8 | 6 | 2 | 7 | 13 | 4 | ...... | 8 | 14½ | 1½ | ...... |
| 30 | 7½ | 10 | 4 | 2½ | 7½ | 13 | 2 | 1½ | ...... | ...... | ...... | ...... |
| 31 | 8 | 11 | 3 | 2 | 8 | 12 | 4 | ...... | 9 | 13 | 2 | ...... |
| Feb. 1 | 8 | 12½ | 2 | 1½ | 6 | 13 | 3 | 2 | 8 | 12 | 2½ | 1½ |
| 2 | 8 | 12½ | 3½ | ...... | 10 | 11 | 3 | ...... | 7 | 15 | 2 | ...... |
| 3 | ...... | ...... | ...... | ...... | 8 | 13 | 3 | ...... | 6 | 16 | 2 | ...... |
| Av.... | 8 | 11¼ | 3¼ | 1⅓ | 7¾ | 12¾ | 3 | ½ | 8 | 13½ | 2¼ | ¼ |

[1]Chiefly "calisthenics" (marching, dancing, apparatus work) and ice hockey; also 3½ hrs. snow-shoeing, 25 mins. riding bicycle ergometer; "endurance test"; motion pictures.

[2]Gymnasium work and hockey, 25 mins. riding bicycle ergometer; "endurance test"; motion pictures.

[3]One hr. gymnasium work; 20 mins. riding bicycle ergometer; "endurance test"; motion pictures.

### EXERCISE RECORDS FOR SQUAD A.

The records for Squad A are given in table 194. They were kept for most of the time from January 11 until February 2 or 3, inclusive. Although the men endeavored as far as possible to classify their activities, and it can be seen that commonly there was uniform regularity in so doing, it is obvious on individual days there may be rather gross deviations from the exact facts. On the whole, however, the picture of all members of Squad A may be taken as indicative of their activity during this period. The records in the table are given on the quarter-hour basis.

*Lying.*—An examination of table 194 shows that usually the men were lying not far from 8 to 9 hours per day. The exception to this

TABLE 194.—*Exercise records during reduced diet—Squad A*—continued.

| Date. | Greyson C. Gardner. | | | | Otto A. Gullickson. | | | | Kirk G. Montague. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lying. | Sitting. | Walking. | Exercise greater than walking.[1] | Lying. | Sitting. | Walking. | Exercise greater than walking.[2] | Lying. | Sitting. | Walking. | Exercise greater than walking.[3] |
| 1918. | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* |
| Jan. 11 | ...... | ...... | ...... | ...... | 5½ | 8 | 6 | 4½ | 7 | 8 | 9 | ...... |
| 12 | 9½ | 9 | 5½ | ...... | 8 | 10 | 6 | ...... | 7 | 5 | 12 | ...... |
| 13 | 8 | 12 | 4 | ...... | 6 | 11 | 5 | 2 | 5 | 12 | 7 | ...... |
| 14 | 9¼ | 6½ | 4¾ | 3½ | 4½ | 7 | 7½ | 5 | 4 | 7 | 10 | 3 |
| 15 | 8 | 8 | 2 | 6 | 3 | 11 | 4 | 6 | 7 | 6 | 8½ | 2½ |
| 16 | 10 | 6 | 5 | 3 | 5½ | 6½ | 7 | 5 | 8 | 7 | 7 | 2 |
| 17 | 9½ | 6½ | 2 | 6 | 4 | 4 | 10 | 6 | 7 | 10 | 4½ | 2½ |
| 18 | 12 | 8 | 2 | 2 | 4½ | 6 | 6½ | 7 | 5 | 13 | 4½ | 1½ |
| 19 | 11 | 8 | 4¾ | ¼ | 5 | 4 | 7 | 8 | 6 | 7 | 10 | 1 |
| 20 | 8¼ | 12 | 3¾ | ...... | 5½ | 5 | 9½ | 4 | 7 | 9 | 8 | ...... |
| 21 | 12 | 9¼ | 1 | 1¾ | 4 | 3 | 10 | 7 | 5 | 13 | 5 | 1 |
| 22 | 13 | 8 | 2 | 1 | 3½ | 6 | 8 | 6½ | 6 | 9 | 9 | ...... |
| 23 | 8½ | 10 | 3½ | 2 | 3 | 11 | 4 | 6 | 6 | 10 | 7 | 1 |
| 24 | 10 | 11¼ | 1¼ | 1½ | 4 | 9 | 7 | 4 | 5 | 12 | 7 | ...... |
| 25 | 12 | 10 | 1 | 1 | 4½ | 10 | 4½ | 5 | 6 | 14 | 3½ | ½ |
| 26 | 8 | 12 | 4 | ...... | 3 | 9 | 7 | 5 | 5 | 12 | 6½ | ½ |
| 27 | 11½ | 11¼ | 1¼ | ...... | 6 | 10 | 4 | 4 | 5 | 14 | 5 | ...... |
| 28 | 9 | 13 | 1 | 1 | 5½ | 10 | 5 | 3½ | 7 | 8 | 8 | 1 |
| 29 | 13½ | 8 | ½ | 2 | 3½ | 8 | 9 | 3½ | 6 | 8 | 8 | 2 |
| 30 | 9½ | 12 | 1½ | 1 | 4 | 9 | 7 | 4 | 5 | 10 | 8½ | ½ |
| 31 | 5 | 16 | 1 | 2 | 4 | 8 | 8 | 4 | 5 | 12 | 4½ | 2½ |
| Feb. 1 | 6½ | 12 | 2½ | 3 | 3½ | 8 | 10 | 2½ | 6 | 5 | 11½ | 1½ |
| 2 | 10 | 10½ | 3½ | ...... | ...... | ...... | ...... | ...... | 8 | 10 | 6 | ...... |
| 3 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 6 | 6 | 12 | ...... |
| Av.... | 9¾ | 10 | 2½ | 1¾ | 4½ | 7¾ | 7 | 4¾ | 6 | 9½ | 7½ | 1 |

[1]Gymnasium work at college, skating, wrestling, basket ball, hockey, running, teaching gymnastics, and coaching basket ball at High School; 20 mins. riding bicycle ergometer; "endurance test"; motion pictures.

[2]Work at Boys' Club, tending boiler and furnace, scrubbing floor, gymnasium work, basket ball, wrestling, skating, ice hockey; 30 mins. riding bicycle ergometer; "endurance test"; motion pictures.

[3]Gymnasium work, wrestling and skating; 30 mins. riding bicycle ergometer; "endurance test"; motion pictures.

was *Gul*, whose average figure shows but 4½ hours. *Gul*, throughout the entire period of observation, was referred to frequently by all members of the squad and by other men in the college as being the "hardest worked man in college." We may record here that no other man in the squad was observed to be more often dozing or nodding, when unemployed and sitting in a chair in the library at the Nutrition Laboratory and at other times. It would therefore appear as if the 4½ hours lying was a low estimate for the resting of this man. In consequence, the estimates for sitting and walking must be somewhat high. It is unnecessary to go into the individual figures to show how the different men vary from day to day, but only to say that the lying values are for the most part remarkably uniform, aside from those for *Gul*.

TABLE 194.—*Exercise records during reduced diet—Squad A*—continued.

| Date. | Henry A. Moyer. | | | | Allen S. Peabody. | | | | R. Wallace Peckham. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lying. | Sitting. | Walking. | Exercise greater than walking.[1] | Lying. | Sitting. | Walking. | Exercise greater than walking.[2] | Lying. | Sitting. | Walking. | Exercise greater than walking.[3] |
| 1918. | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* |
| Jan. 11 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 12 | 8 | 12 | 4 | ...... | 8 | 9 | 7 | ...... | 7 | 8 | 9 | ...... |
| 13 | 8 | 13 | 3 | ...... | 9 | 8 | 7 | ...... | 8 | 12 | 4 | ...... |
| 14 | 8½ | 9½ | 3½ | 2½ | 9 | 6½ | 6 | 2½ | 8 | 10 | 2 | 4 |
| 15 | 7½ | 10 | 4½ | 2 | 10½ | 3½ | 8½ | 1½ | 8 | 14 | 2 | ...... |
| 16 | 7 | 8½ | 4½ | 4 | 7½ | 4½ | 11 | 1 | 7 | 10 | 2 | 5 |
| 17 | 8 | 10½ | 4 | 1½ | 8½ | 6½ | 8 | 1 | 9 | 12 | 3 | ...... |
| 18 | 8 | 10 | 3½ | 2½ | 8½ | 4½ | 10 | 1 | 6 | 15 | 2 | 1 |
| 19 | 8½ | 5 | 5½ | 5 | 8½ | 3½ | 11 | 1 | 8 | 12 | 2 | 2 |
| 20 | 8 | 14 | 2 | ...... | 8½ | 3 | 12½ | ...... | 6 | 14 | 2 | 2 |
| 21 | 8 | 8½ | 4 | 3½ | 8½ | 5 | 10½ | ...... | 8 | 13 | 1 | 2 |
| 22 | 9 | 10 | 4 | 1 | 8½ | 6 | 9½ | ...... | 9 | 13 | 1 | 1 |
| 23 | 8 | 10¾ | 3 | 2¼ | 8½ | 6 | 7½ | 2 | 8 | 13 | 3 | ...... |
| 24 | 7 | 11½ | 4½ | 1 | 8½ | 6 | 8½ | 1 | 10 | 11½ | 2 | ½ |
| 25 | 9 | 10 | 3 | 2 | 8½ | 5 | 9½ | 1 | 9 | 13½ | 1 | ½ |
| 26 | 8 | 13 | 3 | ...... | 8 | 7½ | 8½ | ...... | 7 | 16 | 1 | ...... |
| 27 | 7½ | 14½ | 2 | ...... | 8½ | 7 | 8½ | ...... | 8 | 14 | 2 | ...... |
| 28 | 9 | 9½ | 3 | 2½ | 9½ | 5 | 8½ | 1 | 10 | 12 | 2 | ...... |
| 29 | 7½ | 9 | 6½ | 1 | 7½ | 6 | 9½ | 1 | 10 | 12 | 2 | ...... |
| 30 | 8 | 9½ | 5 | 1½ | 8 | 5½ | 9 | 1½ | 10 | 12 | 2 | ...... |
| 31 | 6½ | 10½ | 5 | 2 | 6½ | 6 | 10 | 1½ | 8 | 13 | 3 | ...... |
| Feb. 1 | 7 | 10 | 4 | 3 | 6½ | 7 | 9 | 1½ | 8 | 12 | 2½ | 1½ |
| 2 | ...... | ...... | ...... | ...... | 5½ | 7 | 11½ | ...... | 9 | 13 | 2 | ...... |
| Av.... | 8 | 10½ | 3¾ | 1¾ | 8¼ | 5¾ | 9 | 1 | 8¼ | 12½ | 2¼ | 1 |

[1]Chiefly janitor work; also gymnasium work, running, and swimming; 25 mins. riding bicycle ergometer; "endurance test"; motion pictures.

[2]Gymnasium work, wrestling, swimming; also ran 1½ miles; 25 mins. riding bicycle ergometer; "endurance test"; motion pictures.

[3]Chiefly hockey; also skating, gymnasium work, and shoveling snow; 30 mins. swimming, and 30 mins. running; 2 hrs. walking in low temperature; 25 mins. riding bicycle ergometer; "endurance test"; motion pictures.

*Sitting.*—With the striking exception of *Pea*, who reports an average of but 5¾ hours sitting, and *Gul*, who reports but 7¾ hours, the men in Squad A showed, on the average, a sitting value not far from 10 to 12 hours.

*Walking.*—The records for walking vary considerably; most of the men averaged not far from 3 to 4 hours. In striking contrast to this are, however, the values for *Gul* of 7 hours, *Mon* of 7½ hours, and *Pea* of 9 hours. Although every effort was made to secure as accurate and objective records for these men as possible, it is clear that errors—indeed, serious errors—crept into these estimates, for an examination of the pedometer records for Squad A from January 14 to February 2 shows that while the correlation between the number of hours estimated for walking and the miles recorded on the pedometer is reasonably constant with most of the men, we have several wide differences.

Thus *Gul* reported an average of 7 hours per day walking, while the pedometer showed but 10 miles. *Mon* reported 7½ hours with a mile-

TABLE 194.—*Exercise records during reduced diet—Squad A*—continued.

| Date. | Leslie J. Tompkins. | | | | Ronald T. Veal. | | | |
|---|---|---|---|---|---|---|---|---|
| | Lying. | Sitting. | Walking. | Exercise greater than walking.[1] | Lying. | Sitting. | Walking. | Exercise greater than walking.[2] |
| 1918. | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* |
| Jan. 12 | ........ | ........ | ........ | ........ | 10½ | 9 | 4½ | ........ |
| 13 | ........ | ........ | ........ | ........ | 8 | 12 | 4 | ........ |
| 14 | 8½ | 11½ | 4 | ........ | 8½ | 11½ | 2½ | 1½ |
| 15 | 14¼ | 9¼ | ½ | ........ | 10 | 8½ | 5½ | ........ |
| 16 | 8½ | 11 | 4½ | ........ | 8 | 7 | 9 | ........ |
| 17 | 8½ | 10½ | 5 | ........ | 8½ | 11½ | 4 | ........ |
| 18 | 8 | 10¾ | 5¼ | ........ | 9 | 10½ | 3 | 1½ |
| 19 | 7 | 12 | 5 | ........ | 9½ | 9 | 5½ | ........ |
| 20 | 8 | 15 | 1 | ........ | 9 | 11½ | 3½ | ........ |
| 21 | 8 | 13 | 3 | ........ | 9½ | 9½ | 3½ | 1½ |
| 22 | 8½ | 13½ | 2 | ........ | 9 | 10½ | 2 | 2½ |
| 23 | 9 | 12½ | 2½ | ........ | 8 | 12 | 2½ | 1½ |
| 24 | 8 | 13 | 3 | ........ | 9 | 12 | 3 | ........ |
| 25 | 10 | 12 | 2 | ........ | 11 | 11 | 2 | ........ |
| 26 | 7½ | 13½ | 3 | ........ | 10 | 10 | 4 | ........ |
| 27 | 7½ | 15¾ | ¾ | ........ | 9 | 12 | 3 | ........ |
| 28 | 8½ | 13½ | 2 | ........ | 9½ | 11½ | 3 | ........ |
| 29 | 9 | 13½ | 1½ | ........ | 10 | 10 | 4 | ........ |
| 30 | 8 | 14 | 2 | ........ | 9 | 11 | 4 | ........ |
| 31 | 5 | 16¼ | 2¾ | ........ | 10 | 9½ | 4½ | ........ |
| Feb. 1 | 10 | 8½ | 4 | 1½ | 9½ | 9 | 4 | 1½ |
| 2 | 6½ | 15½ | 2 | ........ | 6½ | 12 | 5½ | ........ |
| Average | 8½ | 12¾ | 2¾ | 0 | 9 | 10½ | 4 | ½ |

[1]A recent operation prevented Tom from engaging in strenuous exercise and called for a larger percentage of hours sitting. "Endurance test" and motion pictures on Feb. 1.

[2]Gymnasium work and snow-shoeing; 25 mins. riding bicycle ergometer; "endurance test"; motion pictures.

age of 5.8 miles. *Pea* with 9 hours, the highest record, showed a pedometer reading of but 6.2 miles. On the other hand, we have the extremely small value of 2.25 hours with *Pec*, and a pedometer record of 8.3 miles. Under the circumstances a strict comparison of either pedometer records or activity records must be made with great reserve.

*Exercise greater than walking.*—It is particularly unfortunate that we have to rely to so large an extent upon conjecture for this degree of activity. It is clear that in a number of instances the men reported under the head of walking quite a variety of activities which should have been reported as greater than walking, and *vice versa*. According to the records the exercise more strenuous than walking is for all the men somewhat light, *i. e.*, 1 to 2 hours on the average, although we have the excessive amount attributed to *Gul* of 4¾ hours. An admittedly unsatisfactory attempt is made to indicate in a general way the character of the exercise greater than walking; this is shown by the footnotes below the data for each subject. It can be seen that gym-

TABLE 195.—*Exercise records during reduced diet—Squad B.*

| Date. | Edward M. Fisher. | | | | Victor H. Hartshorn. | | | | Karl Z. Howland. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lying. | Sitting. | Walking. | Exercise greater than walking.[1] | Lying. | Sitting. | Walking. | Exercise greater than walking.[2] | Lying. | Sitting. | Walking. | Exercise greater than walking.[3] |
| 1918. | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* |
| Jan. 10 | 8 | 6 | 5 | 5 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 11 | 7 | 7 | 6 | 4 | ...... | ...... | ...... | ...... | 6 | 10 | 2½ | 5½ |
| 12 | 8 | 6 | 5 | 5 | 9½ | 4 | 8½ | 2 | 8 | 8 | 4 | 4 |
| 13 | 9 | 8 | 3 | 4 | 9½ | 7½ | 7 | ...... | 9 | 7 | 5 | 3 |
| 14 | 8 | 7 | 4 | 5 | 9 | 7½ | 5½ | 2 | 11 | 9 | 3 | 1 |
| 15 | 7 | 7 | 4 | 6 | 10 | 8 | 4 | 2 | 10 | 6 | 4 | 4 |
| 16 | 7 | 6 | 5 | 6 | 8½ | 8 | 4½ | 3 | 9 | 9 | 5 | 1 |
| 17 | 7 | 6 | 4 | 7 | 7½ | 8 | 6½ | 2 | 9 | 10 | 2½ | 2½ |
| 18 | 7 | 8 | 5 | 4 | 7½ | 9 | 6 | 1½ | 6 | 9 | 5½ | 3½ |
| 19 | 8 | 7 | 5 | 4 | 8 | 10 | 6 | ...... | 9 | 9 | 5 | 1 |
| 20 | 8 | 9 | 3 | 4 | 10 | 10 | 4 | ...... | 12 | 10 | 2 | ...... |
| 21 | 8 | 7 | 6 | 3 | 8½ | 9 | 6 | ½ | 11 | 10 | 2 | 1 |
| 22 | 8 | 7 | 5 | 4 | 9 | 11 | 4 | ...... | 10 | 9 | 3 | 2 |
| 23 | 7 | 7 | 6 | 4 | 8 | 11 | 3 | 2 | 9 | 11 | 4 | ...... |
| 24 | 8 | 7 | 5 | 4 | 7½ | 10 | 4½ | 2 | 9 | 9 | 4 | 2 |
| 25 | 7 | 5 | 6 | 6 | 8 | 10 | 6 | ...... | 7 | 9 | 5 | 3 |
| 26 | 7 | 4 | 6 | 7 | 11 | 11 | 2 | ...... | 8 | 8 | 7 | 1 |
| 27 | 8 | 6 | 7 | 3 | 9 | 10 | 5 | ...... | 7 | 12 | 5 | ...... |
| 28 | ...... | ...... | ...... | ...... | 8 | 10 | 6 | ...... | 8 | 10 | 5 | 1 |
| 29 | ...... | ...... | ...... | ...... | 7½ | 11½ | 5 | ...... | ...... | ...... | ...... | ...... |
| Av.... | 7½ | 6¾ | 5 | 4¾ | 8½ | 9½ | 5½ | 1 | 8¾ | 9½ | 4 | 2 |

[1]Chiefly gymnasium work and cleaning swimming pool; also swimming, skating, and dancing.
[2]Chiefly gymnasium work, also ice hockey, skating, scrubbing swimming pool, shoveling snow and running.
[3]Chiefly gymnasium work, basket ball, and skating; also running.

nasium work in various forms plays, as is to be expected, rather an important rôle. The work on the bicycle ergometer is not shown in the individual records but is given in the footnotes and taken account of in computing the average per day.

### EXERCISE RECORDS FOR SQUAD B.

Squad B, having been put upon restricted diet on January 8, kept records of their activity similar to those of Squad A in the period from January 10 to 29, inclusive. An examination of the detailed figures, table 195, shows that in general the men were in bed about 8 hours a day. The hours recorded for sitting vary considerably for the different men, ranging from 6¾ to 12¾, but usually are not far from 9 to 10. The hours spent in walking are reasonably uniform, from 4 to 5 hours, while the exercise more strenuous than walking varies considerably, the majority of the men indicating not more than 1 or 2 hours. There is a striking exception in the case of *Fis* (4¾ hours).

TABLE 195.—*Exercise records during reduced diet—Squad B*—continued.

| Date. | Robert L. Hammond. | | | | Harold L. Kimball. | | | | Robert H. Long. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lying. | Sitting. | Walking. | Exercise greater than walking.[1] | Lying. | Sitting. | Walking. | Exercise greater than walking.[2] | Lying. | Sitting. | Walking. | Exercise greater than walking.[3] |
| 1918. | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* |
| Jan. 11 | ...... | ...... | ...... | ...... | 7½ | 10 | 3½ | 3 | 10 | 9 | 5 | ...... |
| 12 | 9 | 12 | 3 | ...... | 8 | 8 | 8 | ...... | 10 | 11 | 3 | ...... |
| 13 | 8 | 10 | 6 | ...... | 9½ | 8½ | 6 | ...... | 11 | 10 | 3 | ...... |
| 14 | 7 | 10 | 5½ | 1½ | 9 | 9 | 4½ | 1½ | 9½ | 8½ | 4 | 2 |
| 15 | 8 | 8 | 4 | 4 | 8 | 9 | 5½ | 1½ | 7 | 10 | 4 | 3 |
| 16 | 8 | 10 | 4 | 2 | 7½ | 9 | 6½ | 1 | 10 | 9 | 4 | 1 |
| 17 | 8 | 10 | 4 | 2 | 9 | 9 | 5¾ | ¼ | 9 | 10 | 3 | 2 |
| 18 | 10 | 12 | 1 | 1 | 9 | 12½ | 1 | 1½ | 9 | 10 | 3 | 2 |
| 19 | 9 | 9 | 6 | ...... | 9 | 13 | 2 | ...... | 8 | 14 | 2 | ...... |
| 20 | 8 | 10 | 4 | 2 | 8 | 10 | 6 | ...... | 8 | 12 | 4 | ...... |
| 21 | 9 | 9 | 4 | 2 | 8 | 9 | 6¾ | ¼ | 11½ | 5½ | 5 | 2 |
| 22 | 7 | 10 | 5 | 2 | 8½ | 9 | 5 | 1½ | 9 | 11 | 4 | ...... |
| 23 | 9 | 8 | 6 | 1 | 7 | 9 | 7¾ | ¼ | 10½ | 8½ | 5 | ...... |
| 24 | 8 | 6 | 6 | 4 | 7 | 9 | 8 | ...... | 9 | 7 | 6 | 2 |
| 25 | 8 | 7 | 5 | 4 | 8 | 9 | 5½ | 1½ | 10 | 7 | 5 | 2 |
| 26 | 9 | 10 | 5 | ...... | 8 | 9 | 5½ | 1½ | 11 | 4 | 7 | 2 |
| 27 | 10 | 9 | 3 | 2 | 6 | 9 | 9 | ...... | 9½ | 10½ | 4 | ...... |
| 28 | 8 | 10 | 2 | 4 | 8 | 9 | 7 | ...... | ...... | ...... | ...... | ...... |
| Av.... | 8½ | 9½ | 4½ | 1¾ | 8 | 9½ | 5¾ | ¾ | 9½ | 9¼ | 4¼ | 1 |

[1]Chiefly gymnasium work, shoveling snow, hockey, and skating; also wrestling, running, cleaning cellar and sifting ashes.
[2]Gymnasium work, swimming, and skating; also 5 mins. boxing and 30 mins. running.
[3]Entirely gymnastic exercise except 3 hrs. swimming.

TABLE 195.—*Exercise records with reduced diet—Squad B*—continued.

| Date. | John Schrack. | | | | Alfred Livingstone. | | | | Chester D. Snell. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lying. | Sitting. | Walking. | Exercise greater than walking.[1] | Lying. | Sitting. | Walking. | Exercise greater than walking.[2] | Lying. | Sitting. | Walking. |
| 1918. | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* |
| Jan. 12 | 9 | 8 | 7 | ...... | ...... | ...... | ...... | ...... | 9 | 10 | 4 |
| 13 | 9 | 11 | 4 | ...... | ...... | ...... | ...... | ...... | 9 | 7 | 7 |
| 14 | 9 | 9 | 4½ | 1½ | 9 | 10 | 3 | 2 | 8 | 10 | 6 |
| 15 | 8 | 12 | 3 | 1 | 11 | 8 | 3 | 2 | 7 | 13 | 4 |
| 16 | 8 | 9 | 6¾ | ¾ | 9 | 10 | 4 | 1 | 7 | 14 | 3 |
| 17 | 8 | 10 | 4½ | 1½ | 10 | 9 | 3 | 2 | 7 | 13½ | 3½ |
| 18 | 8½ | 10 | 5¼ | ¾ | 8½ | 11 | 3 | 1½ | 6¾ | 15 | 2¾ |
| 19 | 9 | 11 | 4 | ...... | ...... | ...... | ...... | ...... | 7 | 12 | 5 |
| 20 | 9 | 12 | 3 | ...... | ...... | ...... | ...... | ...... | 8 | 13 | 3 |
| 21 | 8½ | 11 | 4½ | ...... | 8 | 12 | 4 | ...... | 7 | 14 | 3 |
| 22 | 8½ | 10 | 4 | 1½ | 9 | 9 | 4 | 2 | 8 | 13 | 3 |
| 23 | 8 | 9¾ | 6½ | ¾ | 10 | 8 | 4 | 2 | 7 | 14 | 3 |
| 24 | 7½ | 11 | 4¾ | 1¼ | 9 | 9 | 4 | 2 | 7½ | 13 | 3½ |
| 25 | 7½ | 9 | 6¾ | ¾ | 9 | 8 | 4 | 3 | 7 | 14 | 3 |
| 26 | 8 | 7 | 3 | 6 | 9 | 8 | 5 | 2 | 7 | 13 | 4 |
| 27 | 7 | 9 | 8 | ...... | ...... | ...... | ...... | ...... | 8 | 11 | 5 |
| Av.... | 8¼ | 9¾ | 5 | 1 | 9¼ | 9¼ | 3¾ | 1¾ | 7½ | 12½ | 3¾ |

| Date. | George H. Thompson. | | | | Floyd M. Van Wagner. | | | | Elton L. Williams. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lying. | Sitting. | Walking. | Exercise greater than walking.[4] | Lying. | Sitting. | Walking. | Exercise greater than walking.[5] | Lying. | Sitting. | Walking. |
| 1918. | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* |
| Jan. 11 | ...... | ...... | ...... | ...... | 9 | 10 | 2½ | 2½ | ...... | ...... | ...... |
| 12 | 6 | 14 | 3 | 1 | 10 | 10 | 4 | ...... | 7 | 2 | 13 |
| 13 | 9 | 12 | 3 | ...... | 8 | 12 | 4 | ...... | 7 | 14 | 3 |
| 14 | 8 | 11 | 4 | 1 | 8½ | 10½ | 3 | 2 | 7 | 10 | 7 |
| 15 | 6 | 14 | 4 | ...... | 7½ | 8½ | 6 | 2 | 8 | 8 | 2 |
| 16 | 7 | 13 | 3 | 1 | 7½ | 11 | 4½ | 1 | 8 | 13 | 1 |
| 17 | 8 | 14 | 2 | ...... | 7½ | 10½ | 4½ | 1½ | 8 | 7 | 3 |
| 18 | 7 | 12 | 4 | 1 | 7½ | 10 | 5½ | 1 | 8 | 8 | 2 |
| 19 | 4 | 18 | 2 | ...... | 8 | 12 | 4 | ...... | 6 | 14 | 4 |
| 20 | 8 | 14 | 2 | ...... | 8 | 12 | 4 | ...... | 7 | 14 | 3 |
| 21 | 10 | 12 | 1 | 1 | 7½ | 11 | 4½ | 1 | 8 | 12 | 4 |
| 22 | 7 | 14 | 3 | ...... | 8 | 11 | 5 | ...... | 8 | 7 | 3 |
| 23 | 8 | 11 | 3 | 2 | 8 | 11½ | 3 | 1½ | 8 | 11 | 2 |
| 24 | 10 | 11 | 3 | ...... | 8 | 11½ | 3½ | 1 | 8 | 14 | 2 |
| 25 | 8 | 11 | 4 | 1 | 7½ | 12 | 3 | 1½ | 8 | 14 | 2 |
| 26 | 7 | 13 | 4 | ...... | 7½ | 11 | 3½ | 2 | 8 | 10 | 1 |
| 27 | 9 | 13 | 2 | ...... | 8 | 14 | 2 | ...... | 8 | 13 | 3 |
| 28 | 8 | 12 | 4 | ...... | 7 | 12 | 5 | ...... | ...... | ...... | ...... |
| Av.... | 7¾ | 12¾ | 3 | ½ | 8 | 11 | 4 | 1 | 7½ | 10¾ | 3½ |

[1]Chiefly janitor work at Woods Hall (6 hrs.); gymnasium work and wrestling; also hockey, running, and skating.
[2]Chiefly swimming; also gymnasium work, hockey, wrestling, and basket ball.
[3]1 hr. basket ball and 1 hr. running. In calculating the average, included 15 mins bicycle ergometer and 15 mins. exercise of climbing stairs not reported by Sne.
[4]Chiefly gymnasium work; also 1 hr. skating and 1 hr. hockey.
[5]Chiefly gymnasium work; also hockey, wrestling, and basket ball.
[6]Chiefly janitor work and basket ball; also hockey and athletics.

### EXERCISE RECORDS FOR NORMAL SUBJECTS.

Since both Squads A and B were upon reduced diet, A at maintenance level, and B in a transitional stage, the primary object of this record of activity was to find the influence, if any, of the reduced diet upon the number of hours spent in the various activities other than sleeping and sitting. Since both squads were on diet, the values for a squad not undergoing dietetic restriction are of special interest. A group of volunteers kindly offered to make records for a corresponding time. The longest periods were from January 11 to February 3, but there was considerable irregularity in the length of the record. Nevertheless, for most of the group, the picture is probably not far from true. The results are recorded in table 196. The men were lying usually not far from 8 hours, the most pronounced exception being that of

TABLE 196.—*Exercise records of normal subjects during uncontrolled diet.*

[illegible]

[1]Chiefly gymnasium work; also skating, swimming, basket ball, running, hockey and dancing.
[2]Chiefly hockey; also gymnasium work at college, leading gymnasium classes in public school, and shoveling snow.
[3]Chiefly shoveling coal; also basket ball, ice hockey, leading drill and games at Boy Scout meetings; 2 hrs. moving chairs.

TABLE 196.—*Exercise records of normal subjects during uncontrolled diet*—continued.

[1]Entirely gymnasium work except 4 hrs. of snowshoeing.
[2]Chiefly gymnasium work and swimming, also hand ball, basket ball, dancing, club swing and calisthenics.
[3]Chiefly hockey and gymnasium work; also shoveling snow, and swimming.
[4]11 hrs. sawing wood; also gymnasium work, wrestling, swimming, athletics, and basket b

*Edwards*, with but 6 hours lying. The time spent in sitting vari from 6 to 12½ hours, with very considerable irregularities and no mod value. The number of hours of walking was greatest with *Erickso* 8¾ hours. This was probably due to the fact that his record include Sundays with 15 hours walking each, and no time for sitting. This doubtless an exaggerated statement. On the other hand, *Davis*, wl assisted in the pulse records and was thus used to making accura reports, had an average of 7¾ hours per day of walking. The exerci more strenuous than walking, except for *Edwards* with 3½ hours, a *Barckley* with 2¾ hours, was not far from 1 to 1½ hours.

TABLE 196.—*Exercise records of normal subjects during uncontrolled diet*—continued.

| Date. | Owl. | | | | Ruettgers. | | | | Stewart. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lying. | Sitting. | Walking. | Exercise greater than walking.[1] | Lying. | Sitting. | Walking. | Exercise greater than walking.[2] | Lying. | Sitting. | Walking. | Exercise greater than walking.[3] |
| 1918. | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* | *hrs.* |
| Jan. 14 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| 15 | .... | .... | .... | .... | 9 | 12 | 1½ | 1½ | .... | .... | .... | .... |
| 16 | .... | .... | .... | .... | 8 | 12 | 2¾ | 1¼ | 9 | 11 | 2½ | 1½ |
| 17 | .... | .... | .... | .... | 8 | 12 | 4 | .... | 9 | 10½ | 4½ | .... |
| 18 | 7½ | 11½ | 1½ | 3½ | 8 | 12 | 2¾ | 1¼ | 9 | 11 | 2½ | 1½ |
| 19 | 8½ | 9 | 4 | 2½ | 8 | 12 | 4 | .... | 9 | 13 | 2 | .... |
| 20 | 9 | 9 | 4½ | 1½ | 8 | 14 | 2 | .... | 8 | 13 | 3 | .... |
| 21 | 7½ | 12 | 2 | 2½ | 9 | 12 | 1 | 2 | 8½ | 11 | 3 | 1½ |
| 22 | 8 | 13 | 3 | .... | 8 | 13 | 3 | .... | 9 | 10 | 5 | .... |
| 23 | 7 | 12 | 2½ | 2½ | 8½ | 11 | 3½ | 1 | 9 | 11 | 2½ | 1½ |
| 24 | 8 | 13 | 1½ | 1½ | 8 | 13 | 3 | .... | 9 | 10½ | 4½ | .... |
| 25 | 9½ | 10 | 2½ | 2 | 9 | 12 | 2 | 1 | 9 | 11 | 2½ | 1½ |
| 26 | 7½ | 14 | 2½ | .... | 10 | 11 | 3 | .... | 9 | 13 | 2 | .... |
| 27 | 8½ | 12 | 3 | ½ | 10 | 8 | 6 | .... | 10 | 11 | 3 | .... |
| 28 | 8 | 11 | 2½ | 2½ | 8 | 12 | 2¾ | 1¼ | 8½ | 11 | 3 | 1½ |
| 29 | 6½ | 13½ | 3 | 1 | 9 | 13 | 2 | .... | 10 | 9 | 5 | .... |
| 30 | 9 | 12 | 3 | .... | 8½ | 11½ | 3 | 1 | 9 | 11 | 2½ | 1½ |
| 31 | 8½ | 10 | 4 | 1½ | .... | .... | .... | .... | 9 | 10 | 5 | .... |
| Average | 8 | 11½ | 3 | 1½ | 8½ | 12 | 2¾ | ¾ | 9 | 11 | 3¼ | ¾ |

[1]Chiefly gymnasium work, swimming, and running; also wrestling, basket ball, and skating.
[2]Chiefly gymnasium work; also skating and playing hand ball.
[3]Entirely gymnasium work.

COMPARISON OF THE ACTIVITIES OF SQUADS A AND B, AND THE NORMAL GROUP.

We have collected in table 197 the average values found with the various subjects in Squads A and B, and for the group of normal subjects, for the hours of walking and for the activity greater than walking, as these are the two factors that play the greatest rôle in indicating changes in physical activity. With both Squads A and B, the average time spent in walking was 4½ hours, and with the normal subjects, 4¾ hours. For the activity greater than walking we find reasonable uniformity with all three squads, namely, 1¼ hours with Squad A, and 1½ hours for both Squad B and the normal group. The general picture of the data given in table 197 shows that the activities as measured by the time spent in walking or in exercise greater than walking were not strikingly different with any of the three groups. For Squad A the exercise more strenuous than walking is slightly lower by one-quarter hour per man per day, but the real significance, if any, of this small difference can not be determined.

It therefore seems from a study of the pedometer records and of the relatively small differences exhibited by the men in their records of

physical activity in tables 194 to 197, inclusive, that it is highly improbable that any large difference in the activity, either walking or exercise greater than walking, existed on the average with the three squads.

TABLE 197.—*Average exercise records of Squads A and B during reduced diet, and of normal subjects during uncontrolled diet.*

| Squad A. | Walking. | Exercise greater than walking. | Squad B. | Walking. | Exercise greater than walking. | Normal. subjects. | Walking. | Exercise greater than walking. |
|---|---|---|---|---|---|---|---|---|
| | *hrs.* | *hrs.* | | *hrs.* | *hrs.* | | *hrs.* | *hrs.* |
| Bro...... | 3¼ | 1⅓ | Fis...... | 5 | 4¼ | Bar...... | 5⅓ | 2¾ |
| Can...... | 3 | ⅓ | Har...... | 5¼ | 1 | Dav..... | 7¾ | 1¾ |
| Kon...... | 2¼ | ¼ | How..... | 4 | 2 | Edw..... | 6¾ | 3⅓ |
| Gar...... | 2⅓ | 1¾ | Ham..... | 4¼ | 1¼ | Eri...... | 8¾ | 0 |
| Gul...... | 7 | 4¾ | Kim..... | 5¼ | ¼ | Fra...... | 4¼ | ¾ |
| Mon..... | 7⅓ | 1 | Lon...... | 4¼ | 1 | Gru...... | 2¾ | ¾ |
| Moy..... | 3¾ | 1¼ | Sch...... | 5 | 1 | Hod..... | 5⅓ | 2 |
| Pea...... | 9 | 1 | Liv...... | 3¾ | 1¼ | Mac..... | 3¼ | 2 |
| Pec...... | 2¼ | 1 | Sne...... | 3¼ | ¼ | Owl...... | 3 | 1⅓ |
| Tom..... | 2¾ | [1]0 | Tho..... | 3 | ⅓ | Rue..... | 2¾ | ¾ |
| Vea...... | 4 | ⅓ | Van..... | 4 | 1 | Ste...... | 3¼ | ¾ |
| ......... | ........ | ........ | Wil...... | 3⅓ | 2¼ | ......... | ........ | ........ |
| Av.... | 4¼ | 1¼ | Av.... | 4¼ | 1⅓ | Av.... | 4¾ | 1⅓ |

[1]A recent operation for hemorrhoids prevented *Tom* from engaging in strenuous exercise and called for a larger percentage of hours sitting.

## SUBJECTIVE IMPRESSIONS AS TO FITNESS FOR MUSCULAR WORK.

In the preceding paragraphs the records of general physical activity, as indicated by pedometer readings and other data, made as objective as conditions would permit, have been presented and analyzed. The men who were subjects in the experiment naturally had subjective impressions of their own readiness, ability, and performance in physical exercise. The members of Squad A had an extended period over which to observe themselves and each other. They were intelligent men and all unusually interested in physical exercise and bodily well-being. Seven of them were taking the physical director's course in the college. Their observations during and following the experiment, stated in essentially their own words, are as follows:

*Bro.*—November 10: "Enjoy physical work more than last year, no 'logy' feeling, more 'pep'[1] than last year." December 19: "I am walking more than usual lately." February 2: "There have been times in the experiment when I have felt weak in the knees, and seemed to get out of breath easily. The last ten days I have felt better than during the days just following the Christmas vacation." May 21: "The weakness in the knees in the experimental period was particularly noticed in stair-climbing. I found that I used the stair-rail more than usual when climbing stairs. I am sure the diet could not be recommended for soldiers. I have several times said that I should hate

[1]Colloquial abbreviation for "pepper," indicating vim or snap.

to see our soldiers put on that régime. Under the conditions of an athletic contest, two teams may go through substantially the same motions and the same team plays, but one team does it with more snap and gets there quicker; that team is going to win the game. It was just that added snap that the men on the reduced diet lacked, and which would be the essential thing that a soldier must have in order to succeed."

*Can.*—November 10: "Requires more effort to climb stairs, to go out for a walk, and similar activity. One has to use more will power to accomplish the same things. One tires more easily. On one occasion, I felt exhausted after playing soccer in which I walked about 16 miles in all." November 24: "Heavy gymnasium work yesterday and got very tired." January 12: "Since vacation I have felt the same as at the beginning of the experiment, generally tired, with feelings of weakness." January 26: "One day I may feel good, the next have a great lack of 'pep'." February 2: "To-night I feel pretty 'rotten' as a result of yesterday's endurance test." February 8: "There is no weakness now and I have much more 'pep'. I have not been lying down at noon time as I did during the experiment to save myself." May 22: "In general, lack of endurance was manifested in athletics in my case. Think I could not have kept up the low diet much longer. I believe that if the military were on the same régime, the efficiency of the individual soldier would be decreased." During the experiment he adopted the method of hurrying up and down stairs to get it over with on account of the uncomfortable feelings in the knees and thighs.

*Kon.*—November 10: "The staying power has not been very great; have noticed absence of 'pep'. Feel weak in the afternoon when running with football." February 8: "Have done but very little physical work since close of experiment and therefore can not make a good comparison; feel stronger."

*Gar.*—November 10: "Physical power very much less than that before low diet, less endurance; tire easier if I walk any distance; weakness in legs felt when I go upstairs; very tired after teaching 6 gymnasium classes on alternate days at the high school." December 8: "Feel good physically." January 12: "Felt weaker this morning than at any time while on the squad." February 8: "No improvement in physical work noted as yet; I have not done any gymnasium bar work so far. The first day or so after the experiment I was very sleepy."

*Gul.*—November 10: "Felt normal until the last two or three days, when I experienced weakness, and lack of 'pep'. Somewhat more tired after the boys' club work at night than before, but overcrowded with work." November 24: "A little tiredness in legs develops in the evening, otherwise all right. Worked at writing all last night." December 19: 3½ hours sleep last night; usually take 4½ to 5 hours sleep. I do not have time for more." January 12: "Feel a little faint. It commences to be pretty much of a drain; notice it physically more than before vacation." January 19: "Subject, fasting, completely chinned himself 12 or 13 times in the laboratory." January 26: "Felt good all the week." February 8: "Physical work is below par. Could not do certain exercises in gymnasium. Think it is because I am eating so much."

*Mon.*—November 10: "Feel weak from hunger; no weakness in the walking upstairs; weakness when running or in football; haven't the 'pep' that I had before, but would not hesitate to scrap with a friend." November 24: "Not so much 'pep' as before the reduced diet." December 8: "Weakness

is not localized in the legs, but is general." January 12: The experimenter said, "Well, you feel bully to-night, don't you?" Reply "No! not bully by a long ways. I am weak, weaker than before vacation, or I notice it more. I returned to college at my prescribed weight." February 8: "There is no weakness now. I can do my physical work better."

*Moy.*—November 10: "Doing the same amount of work as usual, but have felt more tired after it." November 24: "Perfectly normal, only that in going upstairs, legs are decidedly weak." December 8: "Feel normal in every way." January 12: "I have no 'pep' at all; can hardly drag around; felt all right just after I came back from vacation." At no time during the first part of the experiment did he feel the weakness so much as in the reduction period following vacation. February 2: "In general, there was considerable weakness during those periods when the weight was actively being reduced. At other times there was not nearly as much difficulty." February 8: "No feeling of weakness now. In gymnasium work the past few days, I felt 'logy' and sleepy from overeating. Now, when lying or standing, I notice the difference in breathing; seem to breathe deeper, and not so many short breaths as when on diet." May 21: "Notice definite difference between physical condition now and when I was on diet. To-day I was swimming in the lake; after the swim I ran up the hill, a rise of 50 or 60 feet, and then on up to the top floor in the dormitory, which meant climbing three flights of stairs. Upon reaching the top floor, I was of course out of breath, but I had none of the feelings of weakness which I previously reported as characteristic of the diet period. At times during the experiment in going upstairs I felt like putting my hands on my knees and pushing with each step to help myself up, particularly when I went slowly. When on the experiment if the diet squad men had hard gymnasium work, such as iron dumb-bells and iron wands, before the exercises were over, they began to slow up and felt fatigued. They simply could not push out the weights, and would skip a few counts. After the period of uncontrolled diet, the conditions were very different. Men were able to do these things without feeling the same fatigue as before. The change was also marked in my case in swimming. I think men on a diet such as we had would not make very good soldiers. They certainly would not feel like going 'over the top'."

*Pea.*—October 27: Not tired from the 5-mile run this morning. November 10: Legs somewhat weak in the cross-country race this morning. At times, does not feel able to do cross-country work. Muscles of legs have pained him some lately. November 24: Finds that he is weak on the indoor gymnasium work. Until now he has only been doing running this year; recently on one evening he boxed 20 minutes, wrestled for 20 minutes, ran a 2-mile race in 10 minutes, and felt very good afterwards. "With me the more exercise the better, but I feel the weakness in the legs reported by the other men." December 8: Still has weakness in the legs. December 12: "This morning is the first time in two months that I have been able to run up all the flights of steps to the fourth floor two steps at a time. I feel fine." December 19: Physically never felt better than during last 10 days; not bothered about going upstairs now. In gymnasium apparatus work, however, he has no strength in his arms. No desire for diving and swimming, as he usually has. January 26: During last fortnight has not felt nearly as well as before Christmas. Tired and weak most of time, having the same amount of exercise as before Christmas. He cannot perspire with any kind of exercise now. February 2: "In the cross-country running in the fall I noticed hardly any change, except in lack of ability to sprint at the end of the race.

not recovering from my operation as I should and my physical condition is poor." February 8: Has more "pep" and strength than at the close of the diet period.

*Vea.*—October 27: "Played tennis all the morning. I am feeling all right." November 10: Feels about the same, except legs get a little more tired than usual. Has been doing more work than usual in order to reduce. "If I could eat food that would go to my legs I would feel all right. My legs are weak. I notice it particularly when walking upstairs. It can not be because of an over-amount of exercise." November 24: Past week much tiredness in legs. January 12: Noticed a little tiredness in the legs. January 26: "This week I have been tired all the time. I do not know why." May 21: "The sensation of weakness in the legs was not so prominent when I was running. It is all gone now."

Certain members of the faculty were especially competent to pass judgment upon the physical fitness and performance of the men. They were continually observing them in their gymnasium and other athletic activities. These instructors discussed the matter with us very frankly. The individual interviews were on May 21, 1918. We are greatly indebted to these gentlemen for the privilege of including their statements which have been made from as nearly as possible an unbiased point of view. They were all heartily in favor of having the experiment carried out at the college and aided us in every way possible.

Professor George B. Affleck said: "The physical endurance of the men was not up to normal when they were on the diet. For one thing, they would ask for the privilege of wearing their sweaters during the exercises in athletics, and whenever possible they would seek to be near the radiators. Then, in the athletic work, some of them tried to play hockey, others to engage in the swimming and other athletic sports. Their endurance was less than in previous years and also was less than that of their fellows. It is impossible to say whether this was because they were physically unable to do the task or were lacking in desire. It may have been partly mental attitude although they seemed to want to do it and keep up with the others. I think in general it might be said that the men on the diet were more passive. They did not seem to feel so strongly. They certainly did not persevere in an athletic contest as one would think they should. They did not have the fighting spirit nor the determination to win. They were not so boisterous and overflowing in spirits as the other students or as themselves before and after the diet."

Mention was made that the men complained of weakness in the legs, and yet at times were seen to be running up and down stairs as occasion or interest prompted. Professor Affleck commented as follows:

"Yes, they complained to me a good deal about the weakness at times in stair-climbing. I think it quite compatible that a man should thus complain and yet be seen to run up or down stairs. This running is largely a habit. Then, too, there is a good explanation, although it may not have been thought of by some of the men. It takes a certain amount of time for the troublesome and more or less unpleasant sensations connected with weakness in stair-climbing to come to the foreground, just as it takes time for certain

fatigue effects to develop. It is possible that one may by running so shorten the process as to avoid, in part at least, the unpleasant sensations."

Professor Affleck felt secure in the conviction that the men on low diet would not make good soldiers. He said:

"They did not have the proper spirit of 'punch' for fight. It was often noted that they were tired, lax, and not so alert as usual, unless they urged themselves especially to the effort."

Professor Austin G. Johnson, as explained on page 396, studied the men while they rode the bicycle ergometer. Concerning the work which the men performed, he made the following general statement:

"Very frequently after a man on low diet had finished riding on the bicycle ergometer, and was lying on the plinth, he would say 'I should like to stay right here for two hours,' or would make some other remark, or by action show the fact that he was fatigued. Such remarks and indications were more frequent and pronounced with the men in Squad A than with the members of Squad B."

Professor Johnson made an interesting observation concerning the matter of perspiration during and following the ergometer work.

"During the low-diet period, the men in Squad A perspired only slightly during the exercise of riding while the Squad B men on full diet perspired very freely, in great contrast to the low-diet men. After the end of the experiment with Squad A (February 3), they did not ride on the ergometer again until February 8. In the meantime their weight had increased considerably and the difference in perspiration was astonishing. *Gul* perspired fearfully upon this latter occasion and panted in a striking and unusual way. Others of the men were noted to perspire very freely in contrast to their former condition, and they appeared to be much out of breath following the work."

Professor Elmer Berry had the following statements to make:

"I am glad that you have not recommended for the military and for men doing hard muscular work a dietetic régime such as that involving the degree of reduction in food in these experiments. Certain of the men of Squad A regularly had what would be regarded as hard, muscular work in athletics; Peabody, for example, and Gardner, also Kontner, who played football a good part of the season. In general most of the men were doing the usual amount of athletic work. While it is true that Peabody and Gardner carried on their heavy physical work, the former doing particularly well in his cross-country races, yet it is my impression that the men generally were definitely below par in their performance. My impression of the men in the gymnasium, for instance, is that they did not seem to be physically fit to do some of the heavier apparatus work. To be sure, this condition may not be entirely due to the diet as the circumstance of less sleep and the many details in connection with the experiment which drew upon the energies of the men were no doubt contributing factors. The feeling of cold was particularly prominent and the men had to be relieved from some of the swimming work on account of the complaints of severe cold. In reality the water in the natatorium was rather warm and no complaints were made by the other men. I think there may have been a slight disinclination for quite so much work in the gymnasium. In general, as a conditioner of men and as an athletic coach I have

these very definite opinions in regard to this diet and its relation to the fitness of men for athletic performance."

Professor Louis C. Schroeder had immediate charge of the gymnasium work of the men. On the occasion when he came to interview one of the authors, he stated that he had some definite ideas about the men and their physical condition during the diet experiment. These he gave without being questioned.

"The program in gymnasium work consists of an hour and a half each day for 5 days of the week. They spend about 7 minutes in marching, 20 minutes in vigorous calisthenics, 30 minutes in apparatus work, 20 minutes in gymnastic dancing, and about 10 minutes in a game. In the calisthenic work the men simply did not have the endurance; they would work quite well for about 5 minutes and after that could not keep up with the other men in the class. With the apparatus work they did not have the strength to do what is here (at Springfield) considered the ordinary senior apparatus work; strength was lacking. What was true of the calisthenic work was also true of the gymnastic dancing, which was more vigorous than the calisthenics.

In the apparatus exercises on parallel bars, in which there was considerable support work, as, for example, in doing shoulder stand, the men on diet did not have the motor control or the strength that was demonstrated by the others or had been previously shown by themselves; they did not come up to expectations. I am not saying they would make a poor showing in all gymnastics and athletic work. In our calisthenics here at Springfield the efforts demanded are what you might call of an explosive type—quick and intense; they do not require the same qualities, perhaps, as the running of a long distance race, but might be better likened to the sprint at the finish. Any particular explosive calisthenic exercise might be repeated 20 or 30 times successively and in this sense, they test endurance."

When asked about the application of such a dietetic régime to the life of the soldier Professor Schroeder said:

"In long rhythmic marching, when the men would gradually work into it, I have no way of judging whether the individuals on such a diet could stand up to the game with their fellows or would be better or poorer. But in circumstances requiring intense, extreme exertion, the gymnasium experience would indicate that this sort of a food reduction, at least in the degree here employed, would place the soldier in a very precarious condition."

Professor Schroeder made the following comments concerning Peabody, who served as his assistant during the winter and conducted the army work class in calisthenics and games 1 hour per day:

"The standing of the cross-country teams with which we contested this year can not be stated surely. I do not know if they were better, poorer, or of average ability. Considering the large number of college men who are now in Government service, some might assume that the teams would not be up to standard. Nevertheless, we were all enthusiastic over the remarkable physical ability and endurance which Peabody showed in these races. In the gymnasium, however, he was not able to perform up to his standard on the apparatus. In the rapid calisthenics he showed more energy and endurance than any other man in Squad A.; there is no question about it. I am not ready to admit that he did as well as usual."

Concerning the particular matter of weakness in the knees and in stair-climbing, Professor Schroeder made this comment:

"The men frequently mentioned weakness in the legs, and you will observe, or at least it seems to me, that stair-climbing calls for just that type of intermittent, intensive exertion used in the calisthenics and gymnasium work which I have described.

"No tests in the nature of quantitative endurance or strength tests were applied in the college gymnasium during the period of the experiment, and no effort was made to play the men on low diet against others for the purpose of seeing what they could do."

Comments concerning physical condition and performance might have been multiplied almost endlessly. The subjects were not encouraged to discuss at length conditions and impressions of this nature until at the end and after the experiment, for we recognized fully that subjective impressions of one's physical activity are often very misleading and inaccurate, particularly in judging the fineness and adequacy of muscular performance. The feeling of ease and success is, however, a most important matter. Any alteration in dietetic habits naturally tends to make an individual more or less introspective. Perhaps the majority of the men when they began the experiment had the general notion that they ate too much. It is only surmised that on this basis some might expect to be more efficient on the reduced diet. On the other hand, one of the most competent subjects remarked in an interview: "I think that during the diet we were rather 'scouting for trouble'." There is no doubt but that among themselves the men frequently discussed and compared notes on their individual conditions. Under the circumstances, with the men living together and eating at the same table, this could not well be avoided.

Notwithstanding these limiting conditions, which are of course not peculiar to this experiment alone and which make it impossible to evaluate accurately their subjective evidence, the comments from both men and instructors are so uniform and there are so few clear contradictions that the following conclusions regarding physical condition and activity seem tenable. Associated with the prolonged period of reduced diet the individuals studied frequently experienced:

(1) Feelings of general weakness and tiredness, a condition commonly expressed in college slang as lack of "pep" or drive, when it seemed to require more energy to accomplish a given amount of work and it was necessary to urge oneself harder.

(2) Weakness of the legs and accompanying unpleasant sensations of fatigue, particularly in stair-climbing.[1]

[1]Concerning the prominence of statements about weakness and fatigue in stair-climbing, there is one circumstance in the arrangement of the experiment which is of considerable importance. The respiration laboratory was located on the fourth floor. Here also arrangements were made for the collection of urine and feces. This rather unfortunate location necessitated for many of the men that they make a trip up and down three flights of stairs for every urination and many defecations, for all the Springfield experiments, to see notices posted on the laboratory bulletin board, make appointments, etc. This probably increased the necessary amount of stair-climbing during the months of the low-diet experiment.

(3) Subnormal gymnasium and athletic performance, as shown by inability to continue the rapid calisthenics or to do the heavy apparatus work for the prescribed time and with the usual subjective satisfaction, and generally to produce effectively sudden bursts of energy.

These feelings or experiences were not homogeneously distributed throughout the whole period of 4 months, during which the reduced-diet experiment lasted. The adverse criticisms apply for the most part to the periods of low diet intake, *i. e.*, during the periods of transition. During the 2 or 3 weeks prior to the Christmas vacation, a period we have selected as one of our maintenance periods, and again during a similar maintenance period near the end of the experiment, unfavorable comments were rare. The men said that they could get on indefinitely at that level and that their working ability was sensibly normal.

## PHYSICAL CONDITION AND ENDURANCE TESTS.

A permanent record of the physical condition of Squad A was made on February 1 by a series of motion pictures. After a few weeks or months the personal impression of the appearance or action of a group of men becomes very indefinite, but a motion picture gives a permanent record of the exact occurrences and condition at the time of taking the picture. In all the pictures it was arranged that one of us should indicate the speed of action by swinging an Indian club to the beat of a metronome timed in seconds. Thus on the projection of the pictures one could see instantly whether the movement was abnormally rapid or abnormally slow. By timing the reproduction to correspond to the movement of the Indian club, the actual time of the movements of the subjects could be determined. This method of recording the rhythm of movement has been very successful, although special projection conditions are necessary. These motion pictures showed the men (1) in four typical gymnastic exercises, (2) "chinning the bar," and (3) diving from a springboard. After the men had dressed and eaten dinner, they returned to the gymnasium for an arm-holding contest to determine their physical endurance.

For the motion pictures in the morning, the men put on black swimming jockey straps and assembled in the gymnasium under the leadership of Mr. Greyson C. Gardner (*Gar*), who had been teaching gymnastics in the Springfield high school during the winter. The four typical gymnastic exercises involved considerable muscular activity. Possibly the most fatiguing and the longest continued was that designated in gymnasium parlance as "arm flexions with stride jumps." The men went through this exercise at a very rapid tempo, accomplishing 17 jumps in 18 seconds. Two sections of film were made for these four exercises, the second section showing an exact duplicate of the series of exercises performed for the first section of film. After the test for "chinning the bar," which will be discussed in detail later,

the subjects went to the natatorium and first dived in succession from the springboard, then at a signal dived together into the water. Undoubtedly the men were somewhat stimulated in these tests by their novelty. They certainly showed vim and spirit which seemed almost impossible with a group of men who had been on a restricted diet for so long a time. It has been the consensus of opinion of the many scientists who have seen the projection of these films that the men neither looked nor reacted as if underfed.

After a long period of extremely low diet it is necessary to know the effect upon not only the metabolism, pulse-rate, blood pressure, and other measurable physiological factors, but to secure, so far as possible, relevant evidence regarding endurance. Much of this evidence must depend upon introspection and upon the comments of the associates of the men in college. Such evidence has already been commented upon *in extenso*. Although the neuro-muscular tests reported earlier gave information as to the capacity for work under special conditions, and the pedometer records and personal activity records of the men also provided a reasonably accurate index of the total activities of the day, further direct evidence regarding the endurance and the capacity of these men for more or less prolonged effort seemed desirable.

Certain information as to the physical endurance of the men in Squad A at the end of 4 months of low diet was secured in the motion

TABLE 198.—*Results of "chinning the bar" test, Feb. 1, 1918—Squad A.*

| Subject. | Time suspended on bar. | Number of "pull-ups." | Best previous record and date. |
|---|---|---|---|
| | *Secs.* | | |
| Bro...... | 52 | 12 | 12 (1916). |
| Can...... | 42 | 5 | Feb. 1, 1918, probably best record. |
| Kon...... | 52 | 12 | Never tried before. |
| Gar...... | 57 | 22 | Probably as good a record as ever. |
| Gul...... | 40 | 14 | 24 (1913). |
| Mon...... | 71 | 13 | |
| Moy...... | 37 | 8 | 12 (1917). |
| Pea...... | 74 | 15 | 18 (1916). |
| Pec...... | 37 | 5 | 5–10. |
| Tom...... | 26 | 7 | 12 (1917). |
| Vea...... | 34 | 5 | 15 (1915). |
| Av.... | .......... | 11 | .............................. |

pictures of the "chinning the bar" tests. In these, the 11 men were lined up along a bar about 8 feet from the ground and at a signal were required to jump to the bar, catch it, and chin themselves as many times as they could. They were allowed to choose their own tempo in this exercise. The exact time that the men hung on the bar was subsequently obtained by running off the film and using the metronome beats to determine the time in seconds. The number of pull-ups was

counted for each man, who also made a statement as to his previous best record. Table 198 shows the number of pull-ups for each man, the length of time that the men were hanging on the bar, and the previous best performance of the men. The men thus exercised the arm muscles practically to the limit of endurance.

The length of time suspended on the bar is of itself a test of endurance, and possibly we should have timed this alone without the chinning.[1] The average number of pull-ups (11) is certainly not a discreditable performance for the whole squad, although the competitive element was in part lacking. Each man was supposed to do his best, but as some men were recognized as trained athletes and others were not, keen competition hardly entered into the performance, save, perhaps in the case of *Mon* and *Pea*, who remained suspended a much longer time than the others.

With reference to the best previous performance, *Vea* showed a falling off of two-thirds. That this is a fair criterion hardly seems possible, as the best previous performance was undoubtedly preceded by special or general athletic training for the contest. It is not without significance that the best performance of the squad was made by *Gar*, who reports the record of 22 as probably his best.

The "chinning-the-bar" test, while strongly indicative of endurance capacity, can hardly be suggested as an endurance test capable of general use and particularly for comparison purposes.

A satisfactory test for endurance that meets the requirements of all critics does not as yet exist. In his study of the effect of excessive mastication of food,[2] Professor Fisher, of New Haven, made an extensive series of experiments in which he employed certain simple tests designed to show the degree of endurance.

Among other tests of endurance, Professor Fisher employed that of holding the arms horizontally at the level of the shoulders, with palms of hands down, and reported the results obtained with a group of flesh-eaters and a second group of flesh-abstainers. One of us, P. R., was a member of the second group of subjects. It seemed desirable to apply essentially this type of endurance test to the members of Squad A. Professor Fisher kindly wrote us at length regarding the conditions that should be met in a test of this kind, and due consideration was given his suggestions. The final plan was to have the men hold the arms, palms down, at the level of the shoulders, but pointing forward at an angle of about 45°, the idea being that if they were held directly out from the body and in opposite directions the head would have to be turned from side to side to see that the arms were being held in position; if they were extended directly in front, the arms

[1]Marsh, Psychol. Rev., 1916, **23**, p. 437.

[2]Fisher, Yale Med. Journ., 1907, **13**, p. 205; also Trans. Conn. Acad. Arts and Sciences, 1907, **13**, p. 376.

would hamper respiration. If they were extended in front, at an angle of 45°, they would be easily visible, and otherwise the position would be more comfortable than the first two mentioned.

This form of test was considerably criticized in our discussion previous to its use, and it is only fair to state that as finally employed it did not meet the full approval of any of us, and was particularly criticized by P. R. who had participated in the earlier test. The members of Squad A were favorable to engaging in this competition test. It was not forced upon them.

On February 1, 11 members of Squad A were assembled in the gymnasium; pitted against them were 11 men selected from the college body. None of these latter were taken from Squad B, as Squad B had been on restricted diet and was in the realimentation period. The men were arranged in the form of an elongated horseshoe, with Squad A on one side and the volunteer squad on the other. At a given signal the subjects were told to extend the arms and hold them in the prescribed position. No talking was permitted, and although there were a number of spectators in the gallery, all were cautioned to make no comments, and to refrain from expressing appreciation or disapprobation in any way. We believe from this standpoint the test was successful. Two of us were present and one walked up and down behind either squad, cautioning the men to keep the arms from wavering and not to lower them unduly.

TABLE 199.—*Results of endurance test.*

[Duration, 1 hour; $2^h 28^m$ p. m. to $3^h 28^m$ p. m.]

| Subject (Squad A). | Endurance. | | Subject (controls). | Endurance. |
|---|---|---|---|---|
| | *min.* | *sec.* | | *min.* |
| Tom.... | 18 | 30 | 1....... | 14 |
| Kon..... | 21 | 20 | 2....... | 27 |
| Can..... | 37 | 0 | 3....... | 44 |
| Pec..... | 56 | 30 | 4....... | 60 |
| Bro..... | 60 | 0 | 5....... | 60 |
| Gar..... | 60 | 0 | 6....... | 60 |
| Gul..... | 60 | 0 | 7....... | 60 |
| Mon.... | 60 | 0 | 8....... | 60 |
| Moy.... | 60 | 0 | 9....... | 60 |
| Pea..... | 60 | 0 | 10....... | 60 |
| Vea..... | 60 | 0 | 11....... | 60 |

The experiment began at $2^h 28^m$ p. m. The period of endurance for each man is given in table 199, the members of the control squad being designated by numbers. The experiment was concluded at the end of 1 hour, as other plans had been made. Furthermore, from the previous experience of Professor Fisher, it was deemed hardly probable that any number of the men in either squad could hold out their arms as long as this. Indeed, if we examine Professor Fisher's records, we find that of 15 flesh-eaters tested, the longest period the arms were held out was 22 minutes; the average of all was 10 minutes. Of the 32 flesh-abstainers, 9 men held out the arms longer than 1 hour. The average for the flesh-abstainer athletes was 39 minutes and the average for the sedentary flesh-abstainers was 64 minutes. It is important

to point out that in our test flesh-abstainers did not enter, as both the men in Squad A and those in the competing squad were flesh-eaters.

Whatever opinion one may have as to this test being a true measure of endurance, and obviously with the variance between the data secured by Professor Fisher and by us in our experiment, the test is open to great criticism, it is clear that the members of Squad A as a whole made equally as good a record as the competing control squad. Such tests are at best so uncertain that a strict comparison may not properly be made between the observations of Professor Fisher and our own. It was believed by the spectators that the men in Squad A were more frequently cautioned and kept to the mark more rigidly than the members of the volunteer squad, inasmuch as the arms were extended without appreciable lowering more accurately and more consistently. There was much alternate sagging and raising of arms, however, with both squads. To the observer it would appear as if both squads met identically the same conditions. We have here, if not an actual test of endurance, certainly a test of comparative endurance between a squad on restricted diet and a squad on ordinary diet.

Emphasis should be laid upon the fact that owing to the coal-conservation measures in force at that time, the gymnasium was extremely cold. Most of the spectators and some of the assistants wore overcoats and hats, while the competitors wore ordinary indoor clothing or light sweaters and no hats. Many of the members of Squad A complained of cold hands, and the experimenters observed that the hands of these men were distinctly blue with the cold. Furthermore, Squad A had been through a rather drastic athletic program, including two series of gymnastic exercises, diving, and particularly the exhausting "chinning-the-bar" tests in the morning about 1½ or 2 hours before this endurance test took place. The element of competition also entered into the endurance test, for each member of Squad A was determined to outlast his opponent on the volunteer squad. Probably this stimulus did not obtain as strongly with the volunteer squad, for they had relatively little to gain by a prolonged test, although naturally they did not want to be defeated by their supposedly undernourished competitors.

The only interpretation permissible from this endurance test is that the members of Squad A, after living 4 months on a considerably reduced diet, showed an endurance, as measured by even this imperfect test, equally as good as that of 11 men selected from the college body who were living on full diet.

### GENERAL CONCLUSIONS REGARDING PHYSICAL ACTIVITY AND ENDURANCE.

From the four main indices of capacity for physical performance, namely, pedometer records, activity records, subjective impressions, and endurance test, the first two and the last have demonstrated no material difference between Squad A and groups of students living on

uncontrolled diet. The unfavorable subjective impressions are applicable more particularly to the transitional periods and bear with very much less force upon the period of maintenance. The prime object of this study is to note the capacity for physical exercise of a squad of men whose body-weight has been materially reduced by previous dietetic restriction and who are subsequently given calories for maintenance. Our evidence, more particularly the subjective impressions, clearly indicates that during the periods of low energy intake, *i. e.*, transition periods, the capacity for effective work was materially lowered. That there was not a pronounced indication of a lowering both in the pedometer records and in the activity records is surprising. All four indices of capacity for physical exercise are concordant in showing that at the periods of weight maintenance the members of Squad A, who were not a selected group of prime athletes, lived normal lives, and performed as much physical exercise as was carried out by their colleagues who were not on reduced diet.

## MENTAL ATTITUDE AND SCHOLASTIC WORK.

The food reduction used for Squad A in this investigation may be regarded as a major change in the diet of these men. This reduction was continued for a relatively long time; the men lost approximately 10 per cent in weight and in general lived at this lowered level for about 2 months; certain striking physiological changes resulted. The introspection and comments concerning the diet and physical activity have been presented. From the mental side, also, certain general questions suggest themselves; (1) What was the character of the psychological environment for this experiment? (2) What in general was the mental attitude and disposition of the men during the experimental period? (3) As college students, how did the men of Squad A progress in their studies during the months when they were on reduced rations?

Regarding the first two queries, we have only the comments of the men themselves and of their instructors and other associates. Concerning the scholastic work there is the added evidence of term grades given in the different courses and under the different instructors. It is difficult in the introspection and personal impression material to make a clear separation between that which relates to physical condition and performance on the one side, and mental ability, disposition, and attitude on the other. In fact, no inflexible boundaries can be set. For purposes of analysis, however, we may look at personal comment from the two points of view. In the following notes we have entered those things which seem to relate particularly to the psychological or mental side. There is a very minor amount of duplication between these notes and those given under the heading of physical activity:

INTRODUCTIVE COMMENTS OF SUBJECTS.

*Mon.*—November 10: Feels only fair; too weak; can not concentrate attention. December 8: "I am weak and irritable." January 26: "For the past few days I have had to go to bed early in the evening and study in the morning; I have noticed the weakness more since Christmas." At the end of the patellar-reflex measurements the subject was found to be asleep. February 2: "The chief difficulty with the whole experiment has been the sensation of being continually weak. I think this has not affected my physical work quite so much as it has my studying. I have noticed repeatedly that I could not seem to concentrate my attention on this sort of work." Subject reports himself to have been by habit a very heavy eater before the experiment. February 8:[1] "Can study better now."

*Tom.*—November 10: Thinks he is keener and can do mental work easier since the experiment began. December 8: He is annoyed because the other fellows urge him to take more physical work and reduce faster; says he has not time to do it. "It makes a difference if one comes first in the evening in the individual psychological experiment as to how you feel for sleepiness; I notice the difference between now and the previous session. This is the first time that I have been among the first four subjects tested in an evening." December 19: "Feel fine and 'dandy' to-night; have felt pretty good all along, sometimes better than at other times but that just happens anyhow." February 2: "The chief inconvenience of the whole experiment has been the necessity of saving urine and feces and having only one place where this could be put. Besides my studies I manage the college store and am busy every minute of the day. There is no time for me to think about being hungry. I believe that it is because of this extra light physical occupation that I have not noticed the hunger and unpleasantness so much as some of the other subjects. As I have looked over the individuals of Squad A, I believe the men who are worried the most, and seem the most irritable, are those who have the least to do. Some of these subjects get through with their work in the afternoon at 3 o'clock and have nothing to do until supper but study and think how hungry they are. I believe that if I had to study during those periods I would notice the hunger too, but I am active, having to wait on customers, and subject to the demands of other people and my attention is occupied." February 8: "Now on the full and uncontrolled diet I am not quite so keen mentally as during the first part of the experiment. Immediately after the experiment was finished and when I began eating heartily again I had a tremendous tendency for drowsiness following meals when attending classes. This is passing off, but has not entirely disappeared."

*Pec.*—November 10: "Think I am keener mentally than when on full diet. It teaches a fellow a lot, particularly how much he can stand." January 26: "I am quite fit for mental work." February 2: "Am feeling rather better, continually improving; think I grow more fit all the time. During the diet I have not required so much sleep as usual." February 8: "I am sleeping all the time now on the uncontrolled eating. During the experiment there were a couple of papers on which I did not get my usual B mark, otherwise I think my work was normal." We believe that *Pec* was throughout the entire experiment the most optimistic subject of the entire group, but he talked the most about food.

[1]The reader should bear in mind as he goes over this testimony that the experiment ended the morning of February 3, 1918. Any comments dated later than this were in the post-diet period, when the subjects were eating uncontrolled.

*Gar.*—November 10: "Have noticed no particular difference in mental ability; I tire easier when sitting in a chair studying." December 19: "Am looking forward to to-morrow morning" (Sunday uncontrolled dinner). January 6: "I feel all right, considering I am the last man to be tested to-night. This week I have been normal in every way; no trouble at all." February 2: "During the experiment I have been able to do my studying as well as usual, but it has not been so with my physical work. I do not seem to require so much sleep as I used to when on full diet. I believe this diminished sleep requirement is related to the diet. Lately I have had something of a 'don't care' attitude in relation to school work and the experiment also. This may possibly be due in part to the general disorganization of the school work on account of the war." February 8: "There was a definite change in the mental disposition with the diet; crabbedness and irritability developed after about the first 2 weeks and continued mostly during the experiment. So far as I was able to note there was no particular change in the ability to study, except as would be associated with some physical weaknesses."

*Gul.*—November 10: "Believe I am mentally keener than when on full diet. I can study for an examination to better advantage now." February 2: "Have noticed no difficulty or detriment to my mental work while on the diet. In the two years previous I have had a great deal of difficulty in keeping awake in classes, particularly after dinner and breakfast. This year I have not dozed off in a class any time during the experiment; absolutely no inclination to sleep during class lectures. In this way the diet has made me more efficient in my college work." February 8: "I feel 'logy'; it is hard for me to keep awake in class now that I am eating uncontrolled. This morning I was sound asleep in both classes; on the other hand, I have noticed that I do not sleep well at night; I wake up earlier and do not want to."

*Kon.*—February 2: "The chief inconvenience of the experiment has been the weakness and of course the hunger." February 8: "I can now study to better advantage, inasmuch as I do not have the feelings of weakness and the distracting desire for food."

*Moy.*—January 26: "During the week I have had no desire whatever to study; the condition is partly due, no doubt, to the realization that the experiment is about to end." February 2: "The inconvenience of the experiment consists largely in the time required, the getting up early in the morning, which necessitated earlier retiring, and also the time at week-ends for coming down to Boston for the Laboratory experiments there. My studying has been just about the same as last year but I think it has required more will power to stick to it." February 8: "Since the experiment I have been able to work as well as, I would not say better, than when on diet, but at least I can study later, *i. e.*, until 12 o'clock, without weariness. Of course it is not necessary for me to rise so early now. During the experiment when I was hungry I found it most satisfactory to run the typewriter or do some such work rather than try to study. It seemed to me that I could do as much on Sunday afternoon after the uncontrolled meal as I could do in all the rest of the week." May 21: "Looking back over the experiment, it seems that perhaps the men were more or less 'scouting' for trouble when they were on the diet. They were noticing many subjective feelings that at other times would receive but very slight, if any, attention. However, the feeling of weakness or faintness was so prominent and so frequently present that there is no doubting its connection with the experiment. There was also a change in mental attitude. As I told you during that period, I was said by some to be the most crabbed

man in school, and since the experiment ended many have remarked that I acted more like myself. I realize that during the experiment I was more critical and irritable and more ready to pick other people to pieces, and since the uncontrolled eating I have felt different toward my associates. Since I have as much or more work to do now than I did during the diet experiment, I can not believe that it was just the details of the experiment that produced this condition, but think it must have been the reduction in food that caused the increase in irritability. The physical weakness might also act in this way. During the experiment there were several times at the dining-hall when some amusing incidents happened, but they did not appeal to us as being particularly funny, as they would do now; we seemed to have a different and more serious mental attitude. I cared nothing at all for going to shows, which now and before the diet were very attractive to me."

*Pea.*—November 24: "The first three days of this week I could not study." December 8: "Not much ambition for study." January 12: "I have no ambition to sit and study; do not feel nearly so good as when I was eating full diet during the Christmas vacation." February 8: "Wednesday morning I went to sleep in class after the Tuesday evening banquet at Peckham's; I have not noticed any particular change in my studies yet." May 22: While the men would stand a good deal of 'kidding' among themselves, from their squad associates, they were more easily irritated, I think; some of them were judged by outside men to be very crabbed indeed. For example, some of the freshmen who entered college this fall, and had never known the men before, judged their dispositions on the basis of what they found them to be during the experiment; since the experiment has ended some of them have remarked at the considerable change they have found in us and expressed surprise at their previous misjudgment."

*Can.*—November 10: "Thinks his mind may be somewhat clearer than when eating uncontrolled." December 19: Felt good for the most part of this week; studied hard and long last night (until 12 o'clock); feels better than on any previous visit to Boston. February 2: "I think that in general the experiment has caused some decline in efficiency in studying; aside from this and the physical weakness the chief thing noted was the inconvenience of the experiment and the feeling of restraint of having always to stop and consider whether I can do this or that; then there was the trouble of collection of urine and feces." February 8: "I find that I can keep awake, study better, and pay better attention in class than I could on the diet; I have headache and a tired feeling in my eyes as during the experiment." May 22: "Your insistence that the talk about crabbedness is just a joke is wrong. Perhaps crabbedness is not the right word; I know of no better one to express it. The men were certainly more easily irritated during the period of the diet. Things which now appear to be small and insignificant were at that time exceedingly irritating and caused us to complain, particularly in reference to the amount of the food at the table. Our irritability was a subject of common remark among our outside friends; there were individual differences naturally; some of the men were easier to get on with than others. I think a good deal depended upon the scientific interest that the individual had in the experiment and his trying to look at the matter objectively. I believe you would have much more difficulty in trying to conduct the experiment with a group of men who had no scientific interest in the problem and whose enthusiasm for research was not aroused. I am under the impression that my mind was a little clearer for purposes of work during the diet period, but it was not sup-

ported by the endurance on the physical side which made long, continuous study possible."

*Spe.*—"I feel definitely that my fall term of school would have been better had it not been for the experiment. The condition can not be wholly laid to the diet. The interruptions caused by the trips to Boston every other week were rather serious in reference to any school work. While of course the men would not have been studying a great deal on Saturday and Sunday, yet the trip away from school and the anticipation of these week-ends was something of a disturbance to studying. During the fall term I had to force myself more than usual to accomplish my necessary work. Because of my illness I can not give any definite idea about the diet and my condition in the winter term."

*Bro.*—November 10: No change noted in mental ability. January 12: "I feel good to-night, but the past few days I have been unable to study much; I do not have enough to eat." January 26: "I feel better than usual to-night, with the prospect of only one week more of the experiment; nothing special to note, except that I have not accomplished much work." February 8: "During the experiment I found that I could study fairly well immediately following meals, but after a time or when it got to be an hour until the next meal I was hungry and could not sit quietly and study. At such times I found it better to get up and occupy myself in arranging the books on the library shelves." (*Bro* was assistant librarian. See subject's comment on diet, p. 279.) May 21: "During the experiment my mental attitude was such that I thought the studies were interfered with by the diet. As I look on it now, it does not seem that there was much interference aside from the fact that one's interest and attention were more or less occupied with the experiment and with looking forward to meal times. It was just as if a basket-ball game were about to occur; you simply could not help thinking of it frequently. Concerning the matter of mental attitude or disposition, I think it was not a joke but a reality, and in all probability associated with the reduction in diet, although there is possibly some connection with the occasional lack of sleep. We called this condition 'crabbedness.' In my own case I had to work in the library each night until 10 o'clock and I had to get up earlier in the morning; there was no opportunity to make up for lost sleep, and this at times affected my mental attitude, which was frequently that of dissatisfaction and irritability. I recall, as was remarked by myself and others several times, that after Sunday, when the men had had a good meal (and more sleep), they would be decidedly changed in mental disposition and would hardly seem like the same individuals."

*Vea.*—February 2: The experiment has taken considerable of the subject's time and he thinks he has frequently been unable to study as well as usual. "Always thinking of eating". May 21: "Now on the uncontrolled diet it is much easier to do my college work from the standpoint that it is easier to concentrate my attention on it. When I sit down to work I do not continually think of the matter of food. There has been a definite change in mental disposition. Mr. X, who roomed near me, has often said lately, 'Why, Veal, there is 100 per cent change in you since you commenced eating. When you were on that experiment you used to come upstairs, slam your door shut, and commence studying, and you weren't at all sociable.' I also have noticed the change in this regard, but in the experiment it wasn't only just the matter of reduced food; it was the many little inconveniences in connection with the experiment, such as infringements upon the time of the men, so that they

could hardly have been expected to be otherwise than crabbed, and at times discontented."

### COMMENTS OF COLLEGE INSTRUCTORS AND OTHERS.

There were a number of people in and about the college who looked upon the experiment as a more or less dangerous thing for the men who were serving as subjects. Fellow-students would inquire how the men felt, would watch them closely, and express themselves freely and strongly, usually in a way that was not very favorable to the reduced-diet feature of the experiment. The men were frequently asked if they did not feel almost starved. The outsider would suggest that he himself could not walk down the street if he had to live on so little food. A number of the men experienced considerable difficulty when they went home at the time of the Thanksgiving and Christmas vacations. Parents and friends complained at the loss of flesh which they observed and expressed solicitation as to the probable danger and the outcome of the whole affair. In one case a trained nurse, a friend of the family, tried to interfere, strongly urging that the young man should not be allowed to return to college if he persisted in continuing with this "foolish business." *Gul* reported to Mr. Fox, December 7, 1917, that a business man prominent in the Springfield boys' club work had offered his services, and those of some other influential friends to help get *Gul* off the "diet squad."

Another example of the interference from outside people was in the case of *Pec*. A physician whom he knew well said in the presence of himself and some members of his family that he should by all means drop out of the diet experiment, as he was taking great chances with his personal health and might almost any time find himself gripped by some disease. A day or so later *Pec* spoke of this incident and made the following remark to one of us:

"I feel bully, and what do I care about my looks, so long as I feel well and fit. We fellows are not suffering anything like the men in the trenches; the unusualness of the experiment is what challenges people's attention; they can't understand why one is willing voluntarily to go on the food reduction when there is plenty of food on all sides. I shall continue to strive for my 10 per cent weight loss and will say nothing about it to members of my family."

Professor Affleck, commenting upon the school work of the men of Squad A, said:

"I am sure these fellows did not try to use their diet-squad experience or service as an excuse in their college studies. It is my feeling that they wanted very much to show that they were just as good as ever, although on a reduced-diet condition. In their courses there was no special consideration given them by the members of the faculty."

Professor Berry made a number of pertinent comments concerning this phase of the investigation. He said in part:

"I feel sure that the members of Squad A were less affected by the psychological conditions pertaining to the diet and to the experiment in general than

most groups of men who undertake diet experiments. Usually, so far as my observation has been, the psychological influences play a very important rôle in dietetic experiments, particularly in the matter of muscular performance of men under these varied conditions. It is my conviction that the psychological element was less prominent in this experiment, and played a less important rôle than in any other case which has come to my attention. The men were commonly found to be somewhat irritable; they were 'touchy,' like wild cats. For example, it was necessary for me to speak to two of the men concerning a certain matter. I knew the men well and was surprised to find them so irritable and to act as they did on that occasion. I do not feel sure that all this is absolutely bound up with the change to a reduced diet, but it came about in connection with the experiment. With some men it may have been because of the necessity of getting up earlier, with somewhat less sleep, and other more or less aggravating things in connection with the experimental procedure. I believe you will find that there was no measureable difference in scholastic work. There was no tendency to try to pass in the fact of membership in Squad A as an excuse, and I believe firmly that there was no leniency on the part of the faculty in consideration of the fact that these men were serving on this squad. Possibly the time and the details in connection with the experiment may have engrossed the minds of some serving as subjects so that they appeared to take less interest in college activities, but in general it must be conceded that their work was normal."

### CONCLUSIONS REGARDING PSYCHOLOGICAL ENVIRONMENT.

From the foregoing notes and comments it must be concluded that although the psychological conditions were probably as favorable at the International Y. M. C. A. College at Springfield for an experiment of this kind as would be found anywhere else, still there was a certain amount of opposition (negative suggestion) which had to be met by the men who were on the food reduction. The men could not live by themselves. It seems to us now that arrangements should have been made so that they could have had their meals separated from the other men rather than at a table in one corner of the main dining-room. This would have proved a double advantage: (1) the subjects would not have had continually before them the abundant food placed on other tables for their fellow-students, and (2) the other men could not have known how limited was the quantity of food allowed the low-diet subjects. Their dietetic régime and physical appearance were constantly topics of conversation for their fellows. In the nature of things comment would not be generally favorable or enthusiastic. The subjects were loyal and determined to see the experiment through to the end. Nevertheless, the comments of their friends could not but act upon the men as suggestions, and it seems only fair to believe that to some extent at least, these comments gave color to the personal impressions of some of the subjects regarding themselves. The psychological atmosphere, at least, outside the squad was charged with expectation of trouble. What others saw in them, the men, to some extent, may have come to see in themselves, but this matter of suggestion must not be pushed too far.

It must be remembered that these subjects were men, intelligent, and quite capable of forming independent judgment. They became to a great extent a gregarious group; there was a good deal of the spirit of caste and group pride. This engendered a certain amount of combative spirit not favorable for the operation of suggestions from the outside. Comment is practically unanimous as to the change in mental attitude and disposition accompanying the reduction in diet. The men were more irritable, more easily annoyed by each other and by outside associates.[1] As they expressed it, they were more "crabbed." They recognized this in themselves, and others recognized it. Those who had not known them before the beginning of the experiment and who formed opinions concerning them during that period were surprised to discover the difference after the men had begun eating uncontrolled. The men joked about their own irritability only because they recognized it and believed it to be a temporary condition from which they would rally when the food reduction was passed. It seems altogether probable that this irritability may have been due, at least in part, to other things besides the mere reduction in amount of food. However, the indications are that it was most prominent in those times when the body-weight was being actively reduced by an unusually low caloric intake, as in October and early November and also following the Christmas vacation in early January. In December and late January the men commented upon themselves in a much more pleasant way. When they were present at the Laboratory, they laughed and talked much more freely and seemed generally much less irritable, if not, indeed, entirely normal. The crabbedness, so-called, developed prominently in some of the members of Squad B during their 3 weeks' greatly restricted diet from January 8 to 28. Space will not permit giving their comments.

## EFFECT ON MENTAL ATTITUDE.

No reader will doubt the fact that members of Squad A, during the experiment, sometimes found it more difficult to concentrate their attention upon their studies and to sit quietly at work. Who has not at times noted in himself greater difficulty in continuing at such work when the meal time was near at hand or when he was about to start on a journey? It must be apparent to anyone that there were many details about the experiment which called for the cooperation of the subjects, and so, for their attention. It was an added burden and interest which their fellows did not have to carry; it entailed many individual appointments and group meetings, as well as the regular trips to Boston, which occupied Saturday and a portion of Sunday.

[1] Langfeld reported depression and irritability in the case of L, who fasted 31 days at the Nutrition Laboratory (See Benedict, Carnegie Inst. Wash. Pub. No. 203, 1915, p. 191). The experimental program no doubt became more monotonous in the fasting than in this low-diet investigation.

There were new apparatus and scientific methods for them to become acquainted with and interested in. These things could not otherwise than distract their attention somewhat from regular duties. Hence, when a man reports that he has not accomplished much studying during the previous days or has not had much desire to study, those who are acquainted with college life will recognize at once that this is not a condition peculiar to a restricted diet. Considering the experiment as a whole, the men did much more than they could originally have expected to be called on to do, but even so, there was very little complaining, and it was always easy to cheer them up and enlist their support. They proceeded with their college work as usual, regarded the whole thing somewhat as a joke, and made fun of themselves and of others in connection with the matter of eating. Not one of the men would be willing to have the experience omitted from his life.[1]

Aside from some feelings of weakness and discomfiture especially prominent at times of active weight reduction, and some scattering of attention incident to the experiment, the reduced diet as such seems to have had no detrimental influence on the ability for mental work. Several subjects were convinced that their minds were clearer during the diet period and that they were relieved from the annoying tendency to sleep after meals, which tendency returned and was prominent with the excessive eating following the experiment. Some variety of work was found particularly desirable. If at those times, when thoughts of food were especially persistent, and hunger prominent, the subject had some light physical activity to which he could turn, the time until the next meal seemed greatly shortened.

### EFFECT ON SCHOLASTIC STANDING.

To verify the personal impressions regarding the scholastic work of the men who served as subjects in the experiment, we have the more or less objective data of the term grades in the several college courses which were taken. The experiment lasted from October 4 to February 3. The college year is divided into three terms—fall term, from September 19 to December 21; winter term, from January 3 to March 22; and spring term, from April 2 to June 1. The fall term and the first part of the winter term were thus included in the diet period. In table 200 the average term grades for the fall and winter in all the courses taken are compared for each subject with the average of all the grades which the subject had received in all the courses taken previous to

[1]Many things concerning the light side of the experiment and the attitude of the men to it could be mentioned. On the floor of the library at the Nutrition Laboratory, one Monday morning, one of us picked up a slip of paper bearing the following couplet: "Die, die, Diet Squad; Shy, shy, shy a 'pod,'" by which it is meant to be indicated that the girth has been remarkably reduced. Squad A, when the experiment was nearing the close placed a calendar over their table in the dining hall, which bore in large letters the words: "Ten days, and we eat." Each day, to the accompaniment of applause and congratulations, the number of days was decreased one.

September 1917. Of Squad A, 9 men were from the senior class, but *Fre* should not be counted in any comparison, since he served in the squad so short a time; there are thus 8 men whose records are comparable. Of these, 4 (*Can, Gul, Pec,* and *Vea*) show average marks for the diet period which are slightly below their average for all courses preceding September 1917. There are 4 (*Bro, Gar, Moy,* and *Tom*) who show marks as good or better for the diet period. Changes are not large in any case, the largest is one of 4 per cent in the case of *Moy*, whose previous average grade was 87 and whose average grade during the low diet was 91. The whole group of 8 senior subjects taken together show average grades which are identical for both periods, that is, 88.6 per cent. There were 31 other men in the senior class. The average grade for all of these men, prior to September 1917, was 86.3 per cent, and for the same group, during the period of the experiment, the average was 84.3 per cent. There was thus an average

TABLE 200.—*Average grades of members of Squad A during the reduced-diet experiment contrasted with their previous grades, and with those of their fellow classmen.*

| Members of Squad A contrasted with average for the other men in their classes. | Average grade in courses taken prior to September 1917. | Average grade in courses taken in fall and winter terms of 1917–18. |
|---|---|---|
| Squad A—Seniors: | *p. ct.* | *p. ct.* |
| Bro | 92 | 92 |
| Can | 88 | 85 |
| Gar | 88 | 91 |
| Gul | 87 | 84 |
| Moy | 87 | 91 |
| Pec | 91 | 89 |
| Tom | 90 | 92 |
| Vea | 86 | 85 |
| Average for the above 8 subjects | 88.6 | 88.6 |
| Average for the 31 other seniors | 86.3 | 84.3 |
| Squad A—Sophomores: | | |
| Mon | 89 | 92 |
| Pea | 83 | 88 |
| Spe | 79 | 87 |
| Average for the above 3 subjects | 83.7 | 89.0 |
| Average for the 27 other sophomores | 83.0 | 87.0 |

decrement of 2 per cent for those who were not subjects. If this tendency of the class as a whole during the first two terms of this year as compared to the record for previous years is contrasted with the average record for the 8 senior men who were subjects in Squad A, it is perfectly justifiable to say that these men did not do work that was inferior to their previous college work, and their performance was in no way below that of their fellows. Three of the subjects of Squad A were classified as sophomores; these were *Mon, Pea,* and *Spe,* as

shown in table 200. The average grade in the case of these 3 men shows in each instance a better average grade during the period of the experiment, with the result that the 3 men have an average grade of 83.7 per cent for courses prior to September 1917, and for courses during the experiment, 89.0 per cent, an average difference of 5 per cent in favor of the work done during the experiment. The average for 27 fellow-classmen shows an average grade of 83.0 per cent prior to September and an average during the experimental period of 87 per cent. Here is a difference of 4 per cent in favor of the work done this college year. The three sophomores in Squad A, therefore, show the same tendency as the rest of their class, but slightly more marked. Hence after a careful analysis of the term grades for the many courses which had previously been completed and others which were taken during the period of the experiment by these men, it was found that, as a group, during the 4 months' period of reduced diet, they kept their college work up to their own previous standard, and were not inferior to their fellow classmen. The statement of Professor Berry and some of the men that the college work was of usual standard is therefore clearly verified.

## GENERAL POST-EXPERIMENTAL HISTORY.

An important part of our records of this research is the post-experimental history of the men undergoing this experience. Questions which may fairly be asked are: What condition were these men in at the end of the long test? What was their history subsequent to the restriction in food? Were there any permanent effects of the low diet? Did the men subsequently change their dietetic habits on account of their experience?

Owing to the special conditions obtaining at the Y. M. C. A. College in the spring of 1918, when a number of the men left college for Y. M. C. A. military service, it became impossible to obtain such information for all of the men. However, a number of them were seen personally by one of us on a visit to Springfield May 21 to 22, and records were made of their condition at that time. More or less data have also been obtained through correspondence. A special effort has been made to find whether a permanent effect of the low diet was noted by the men themselves. Much of this information has already been given in previous sections, particularly in the section on diet. (See p. 272.)

One general feature of the post-experimental history is the excess eating immediately indulged in by the men. Considerable practical experience has shown that there is danger in taking a large meal immediately after prolonged starvation or even after a period of undernutrition. Evidence on this point has already been given, showing that when the men were allowed uncontrolled diet, they almost invariably overate, notwithstanding repeated cautions. This frequently

resulted the following day in pain in the abdomen or diarrhea and general discomfort. This tendency of the men to eat largely after fast is in full conformity with statements made by Professor Pawlow to the effect that more or less gross feeding usually followed Russian fasts. (See p. 203).

Although all of the subjects were frequently told that if they desired to increase their diet at the conclusion of the test, they should do so slowly and carefully, and not indulge in immoderate amounts of food, the over-indulgence in food was general among the men. As a result, a considerable number of them suffered from abdominal pain, colic, and diarrhea. The experiment ended Sunday morning, February 3. In spite of excessive eating on Sunday and digestive disturbance on Monday and Tuesday, all of the men attended a banquet February 5 given by one of Squad A to the squad as a whole. At this banquet they ate inordinately.

The most direct evidence that we have of the excess eating following the cessation of the diet is the great and rapid rise in the body-weight shown in figures 57 to 68 and discussed in the section on body-weight. In practically every instance the weight prior to the beginning of the experiment was reached almost immediately and was usually materially

TABLE 201.—*Increases in body-weight after resumption of normal diet—Squad A.*

| Subject. | Initial weight. (Sept. 30, 1917.) | Final weight with reduced diet. (Feb. 3, 1918.) | Initial weight regained. | | Maximum during post-experimental period. | |
|---|---|---|---|---|---|---|
| | | | Date. | Days required. | Date. | Weight. |
| | *kg.* | *kg.* | 1918. | | 1918. | *kg.* |
| Bro | 61.8 | 54.4 | Feb. 13 | 10 | Mar. 11, Apr. 29 | 63.0 |
| Can | 79.8 | 69.3 | Feb. 21 | 18 | May 23 | 81.8 |
| Gar | 71.3 | 63.0 | Feb. 25 | 22 | Mar. 11, 14 | 72.5 |
| Gul | 66.8 | 61.0 | Feb. 16 | 13 | Feb. 21 and Mar. 14 | 69.5 |
| Mon | 68.8 | 60.6 | Feb. 20 | 17 | Mar. 11 | 70.0 |
| Moy | 63.5 | 57.8 | Feb. 8 | 5 | Apr. 29 | 71.5 |
| Pea | 69.3 | 61.3 | Feb. 13 | 10 | Mar. 11, 14 | 74.0 |
| Pec | 64.3 | 59.1 | Feb. 13 | 10 | Mar. 14 | 71.5 |
| Tom | 59.5 | 55.1 | Feb. 13 | 10 | May 23 | 64.9 |
| Vea | 65.8 | 58.5 | Feb. 18 | 15 | May 22 | 71.2 |
| Av. | 67.1 | 60.0 | ............ | 13 | .................. | 71.0 |

exceeded. This is shown in table 201, in which are given the initial weight of the members of Squad A prior to the experiment, the weight at the end of the experiment, the date on which the initial weight was regained, with the number of days required for this, and the subsequent maximum weight, with the date upon which it was recorded.

No evidence was obtained that these men, with the possible exception of *Moy* and *Bro*, acquired new dietetic habits or adjusted them-

selves to a lower food intake as a result of the experiment. The circumstances militated against this. In the first place, the men craved food after the restricted diet and especially desired sweets and accessory foods of all kinds. Secondly, subsequent to the research, they were liberally supplied with food in the dining-hall and ate with their college mates without restriction. Environment more than physiological demand was the controlling influence.

On May 22, 1918, all of the men were reported to be in excellent physical condition. But 6 of Squad A were then in college, the others having been called away for duty elsewhere, one of these only temporarily. After May 22, 1918, it was extremely difficult to keep in touch with the men, owing to their being so widely scattered on account of war conditions. We have, through one channel or another, secured the following notes regarding the members of the two squads. All of this information demonstrates success in their various lines of activity and would seem to indicate that the men experienced no ill effects from the experiment.

*Bro.*—May 22: Still in college and carrying on his usual work as assistant librarian; in excellent health. Eating only two meals a day, omitting dinner; thought he was taking less food than normally. Did this for economy, but not entirely as he thought he was better for it. Later in 1918 was in Y.M.C.A. work in the army.

*Can.*—May 22: In college. Had been eating too much and felt need of reduction. Was trying to take only one helping at table. Was married after leaving college, and drafted. In excellent health June 1919; nude weight at that time, 85.5 kg., *i. e.*, 18.0 kg. overweight.

*Kon.*—Was compelled to leave college shortly after the end of the experiment on account of accident to his father. According to information obtained on May 22, he subsequently worked hard in a mine belonging to his father, was gaining in weight, and was feeling very well. Later went to the University of Toronto to train for aviation section of the Army Signal Corps. In the spring of 1919 was physical director of the Young Men's Christian Association, Middletown, Ohio.

*Gar.*—Was drafted and went to Camp Taylor in Kentucky in April; was in excellent physical condition on leaving college. Married April 23, 1918.

*Gul.*—Drafted and left college March 15, 1918, for a few weeks at home in North Dakota before going into the army; while at home worked on the farm. Later went to Camp Dodge, Iowa, as member of the Engineer Corps; afterwards second lieutenant at Camp Hancock, Georgia. Was feeling fine when last heard from. In January 1919 was out of the Army and connected with the Minneapolis, St. Paul, and Sault Ste. Marie R. R. in South Dakota.

*Mon.*—Left college and went to France in May to enter military Y.M.C.A. work as physical director. Was married before he went. In January 1919 was still in France.

*Moy.*—Passed local district medical examination for military qualifications about the middle of March, in Springfield. There was no question as to his physical condition at that time. May 22, thought his record with hand

dynamometer was better than during the low-diet experiment. Was going without supper to save time and money; thought he was eating less than previous to experiment. Appetite less keen since omitting supper. Ate three meals a day up to April 3. During the diet experiment he tried to make the college swimming team, but was too slow. After experiment, he tried again but was too fat; later trained down and made the team. Died of influenza and pneumonia at the Great Lakes Naval Training Station, Great Lakes, Illinois, in the fall of 1918.

*Pea.*—May 21, in college. Said that after the diet experiment he became so heavy that he could not win a place on the track team in the distance run. Was too heavy for the 2-mile race and was trained for the half-mile. In two track meets he did not win a place, although he could reasonably have been expected to have done so, as the year before he had been captain of the track team and best man on the team. His failure was considered as being due to putting on too much flesh after the low diet. When seen May 21, had attended a dance the night before and danced hard until after 12 o'clock. Had influenza and pneumonia in the fall of 1918, but recovered. In January 1919 was lieutenant in the U. S. infantry. April 1919 in Italy as athletic director and organizer for the Young Men's Christian Association.

*Pec.*—Went to France early in April for military Y.M.C.A. service. The vessel he sailed on was torpedoed, and although he was the last man to be awakened, he succeeded in saving his own life and that of another man. In January 1919 was still in France.

*Spe.*—Returned to college on April 2, 1918. Reported to be in good condition. Owing to his serious illness, his body-weight in the spring was essentially that at the time the experiment was begun. Obviously his illness played an important rôle in his post-diet experience and undoubtedly resulted in his more ready adjustment to a normal diet than was the case with the other men. Later in the year was second lieutenant in the Students' Army Training Corps, Columbia University. In the spring of 1919, still in college.

*Tom.*—Married on March 24, 1918. On May 22 was temporarily away from college, assisting in a Red Cross drive at Yonkers, New York, for a week. This work was done in addition to his regular college duties. Was intending to finish his course. Had rallied from his operation, and during the few weeks previous had been in the gymnasium, although as a result of his operation he had not been able to do all the gymnasium work. In general, he seemed to be in good physical condition.

*Vea.*—In college May 21. Later, was drafted for the Army and in June 1918, was at Camp Upton, New York; afterwards went to France as corporal in the infantry and had considerable service in the front lines. In January 1919 was still in France.

*Squad B.*—All of the men in Squad B were in one branch or another of the Government service during the war. *Fis*, *Sch*, and *Van* were in the army (*Sch* in the Medical Corps, and *Van* second lieutenant assigned to the 63rd Pioneer Infantry); *Sne*, *Kim*, *Lon*, and *Tho* were in the navy; *How*, *Ham*, *Liv*, and *Wil* were in the Students' Army Training Corps.

In March 1919 six of the men were in college (*Fis*, *How*, *Ham*, *Liv*, *Van*, and *Wil*), were active in athletics, and in excellent health. *Sne* and *Tho* had graduated. *Kim*, *Lon*, *Sne*, and *Tho* were still in the navy. *Kim* and *Lon* expected to return to college when released, *Sne* was an ensign, and *Tho* was training for a commission. Two of the men in Squad B had married (*Fis* and *Sch*).

## SUMMARY OF RESULTS AND GENERAL CONSIDERATIONS.

From the large mass of data that we have attempted to analyze in this report, certain very striking factors stand out above all others. While on the reduced diet these men underwent profound metabolic changes, which were indicated not simply by the losses in weight but also by alterations in pulse-rate, in blood pressure, to a slight extent in respiration rate, and more especially in the gaseous metabolism.

### CAUSE FOR DEPRESSION IN METABOLISM.

The depression in the total metabolism is, without doubt, the most prominent feature of the entire research, particularly as it was accompanied by a depression in other physiological factors, such as blood pressure and pulse-rate. Loewy and Zuntz[1] also noted a lowered metabolism and give two possible explanations of it. One was that the depression may have been wholly due to a lowered protein intake, the other that there may have been a very considerable decrease in the active cell-substance. The first of these two hypotheses they dismiss, because Loewy, from the nitrogen excretion of the urine, showed that he was living upon a distinctly high nitrogen level. The explanation of Loewy and Zuntz thus rests solely upon the hypothesis that there was a considerable loss of active cell-substance, and they conclude that when the protein content of the diet is large and the caloric intake is insufficient it is impossible to prevent the disintegration of active body-substance. None of our men happened to have as high a nitrogen excretion as that of Loewy, but with some it was fairly large and with others fairly small. Consequently we do not believe that the protein intake of itself played any particular rôle in this case. Loewy and Zuntz naturally lacked demonstration of the loss of protein from the body.

One of the possible explanations of this lowered metabolism is that with a weight-loss there is less work for the musculature to perform in its ordinary activities—less weight to be lifted and less weight to be moved. This may even apply in the case of respiratory and heart muscles. A lower metabolism as a result of reducing the load to be moved would therefore be expected.

A second possible explanation is that with the reduction in diet, and consequent loss of body-weight, there may be a removal of fat from the tissues of the cells that makes the muscles somewhat more flexible, capable of more severe work and greater efficiency. This is perhaps in part comparable to a certain phase of athletic training, which com-

[1]Loewy and Zuntz, Berl. klin. Wochenschr., 1916, **53**, p. 825. As this monograph goes into page proof, our attention has been called to a second article by these authors (Zuntz and Loewy, Weitere Untersuchungen über den Einfluss der Kriegskost auf den Stoffwechsel, Biochem. Zeitschr., 1918, **90**, p. 244), cited in an editorial in the Journ. Am. Med. Assoc., 1919, **72**, p. 574. We are not able to see the original article and in any event it is too late for its analysis in this report.

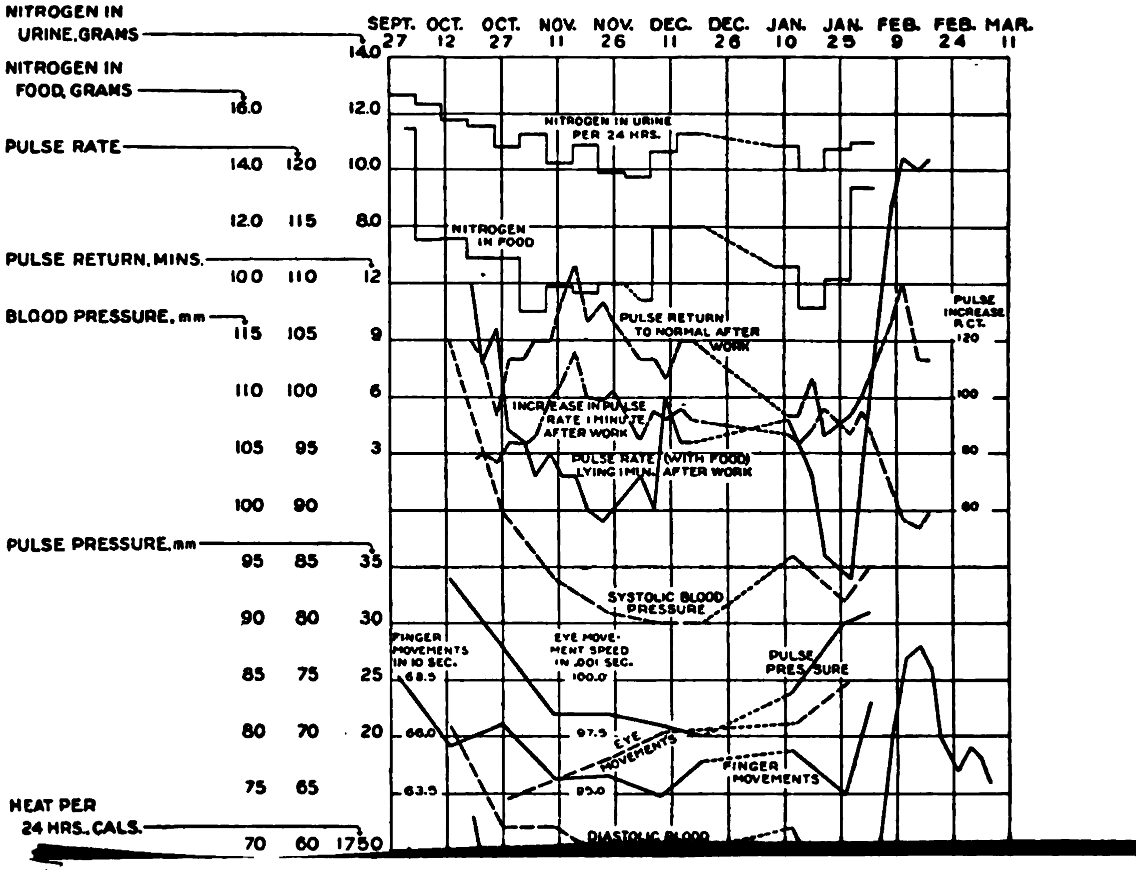
bines the removal of fat by excessive activity with the enlargement of the muscles with practice. Comments made in gymnasium classes implied that the men found the muscles were more free when they were on the reduced diet than when they were on uncontrolled diet.

Since, however, the changes in the metabolism were accompanied in practically all cases by a large loss of nitrogen from the body, the correlation of the nitrogen loss with the lowered metabolism is a natural procedure. With Squad B the general picture is much the same as with Squad A, although as the weight loss and the nitrogen loss were only about one-half those of Squad A, the depressions are not so sharply accentuated as with that squad.

An inspection of the nitrogen figures leads us to believe, however, that the most obvious cause for this lower metabolism is the removal of some 175 or more grams of nitrogen from the bodies of these men, resulting in a withdrawal from the fluids bathing the cells of a large amount of nitrogenous material. This material, which acts as a stimulus to cellular activity, is probably of an acid nature. It is clear that a careful chemical analysis of the blood should have been made.

It is of prime importance to note that in this whole series of experiments with the 25 or more men involved, the picture exhibited by the individual men is almost identical with that shown by the group as a whole. In other words, we have here no exceptions. It is extremely unfortunate that all of the initial members of Squad A could not have completed the 4 months' test. This would have greatly simplified the averaging of the results. Of the original members of Squad A, however, there were 9 men who went through the entire period without a break; we have therefore averaged the values for the most important findings for these 9 men and present these averages in the form of a chart. (See fig. 124.) It should be emphasized at this point that our basal tables and our derived tables for the several factors studied are made up from an analysis of the situation as presented by *all the members* of both squads, and the conclusions are drawn from these figures. The curves given in this chart, however, are drawn from the picture presented by only *9 members of Squad A* [1] So far as we can see, there is little, if any, change in the general appearance of the picture or the interpretation of the data as a result of this curtailment in the number of men. For a general picture showing the influence of low diet upon all the physiological factors mentioned, a chart is preeminently desirable, but in making such a chart it is necessary to average values in so far as possible for the same number of individuals. The body-weight curve, representing a composite curve of the weight changes of 9 men, has a particular interest in that the distinctive features brought out in discussing the individual body-weight curves, namely, the post-Sunday

[1]The 9 men whose data were used for the chart in figure 124 are as follows: *Bro, Can, Gar, Gul, Mon, Moy, Pea, Pec,* and *Vea.*


NITROGEN IN URINE, GRAMS
NITROGEN IN FOOD, GRAMS
PULSE RATE
PULSE RETURN, MINS.
BLOOD PRESSURE, mm
PULSE PRESSURE, mm
HEAT PER 24 HRS., CALS.
SEPT. 27
OCT. 12
OCT. 27
NOV. 11
NOV. 26
DEC. 11
DEC. 26
JAN. 10
JAN. 25
FEB. 9
FEB. 24
MAR. 11
14.0
16.0
12.0
14.0
120
10.0
12.0
115
8.0
100
110
12
115
105
9
110
100
6
105
95
3
100
90
95
85
35
90
80
30
85
75
25
80
70
20
75
65
70
60
1750
NITROGEN IN URINE PER 24 HRS.
NITROGEN IN FOOD
PULSE RETURN TO NORMAL AFTER WORK
PULSE INCREASE % CT.
120
100
80
60
INCREASE IN PULSE RATE 1 MINUTE AFTER WORK
PULSE RATE (WITH FOOD) LYING 1 MIN. AFTER WORK
SYSTOLIC BLOOD PRESSURE
FINGER MOVEMENTS IN 10 SEC.
68.5
66.0
63.5
EYE MOVEMENT SPEED IN .001 SEC.
100.0
97.5
95.0
PULSE PRESSURE
EYE MOVEMENTS
FINGER MOVEMENTS
DIASTOLIC BLOOD

rises and the post-Christmas rise, are all clearly shown in this curve. The striking increase in body-weight following the resumption of normal diet is also prominent.

Although the net caloric intake has been shown on the individual body-weight curves, the average values for these 9 men are here given in blocks closely associated with the average body-weight curve. The difficulty of securing evidence regarding the net caloric intake at the maintenance weight level is more clearly brought out in this composite curve than with the individual curves, for one would expect a smoothing of the curve, indicating even more than is here shown that weight maintenance was obtained in December and again in the latter part of January. Even with the best possible food adjustment, which it will be recalled was specifically planned to maintain the weight at a constant level, we find that the average value for the 9 men shows considerable fluctuation. Yet we see no reason for altering our original statement that during December and the latter part of January these men were essentially at weight maintenance. As was pointed out in the earlier discussion, a change of 1 kg. may not be significant, owing to the large water content of the body, and it is by no means a certain indication of changes in organized body-tissue. The energy intake at the weight level is for the December period 2,200 calories and for the January period 1,950 calories. The average for these 9 men for these two periods is therefore 2,075 calories, which is but little above the average value for the entire squad, namely, 1,967 calories.

It is important to note that in this chart, as in the individual body-weight charts, the net energy intake for the first few days in October, which is here represented as 3,100 calories, should in all probability be nearer 4,000 calories, and would in consequence normally occupy a higher block and correspond more nearly to the general trend of the body-weight curve.

In spite of the striking changes in the net energy intake, as shown by the blocks at the bottom of the chart, the nitrogen in the food represents fluctuations by no means comparable to the total energy. The general contour of the series of blocks indicates that the nitrogen of the diet was not on a particularly low level, but averages about 10.5 grams. The section of the curve for the last few days of the experiment shows a distinctly high nitrogen intake, this being higher than at any other time during the observation, save for the first week of uncontrolled normal diet.

In striking contrast to the nitrogen in the food is the rather level curve for the nitrogen in the urine; that is, in spite of the relatively enormous alterations in nitrogen in intake, we find the nitrogen in urine remains reasonably constant, the lowest point of the curve appearing a few days following November 26. Here again it is well to emphasize the fact brought out in the study of both Squads A and B

that the relative constancy of the nitrogen excretion in the urine under very marked change in intake is one of the surprising features of the research.

The comparison between the nitrogen of the food and the nitrogen in urine leads, of course, to the consideration of the large nitrogen losses. These are so significant and of such magnitude that we have deemed it advisable to plot them in the form of a curve showing the accumulative nitrogen loss, which is a curve that continues downward as the experiment progresses. This appears near the lower part of the chart and shows a final loss at the end of the experiment of not far from 175 grams of nitrogen for the average of 9 men. Sufficient attention has been called in the earlier text to the difficulties of accurately estimating the total nitrogen loss, owing to the uncontrolled days, on the one hand, and to the loss through the skin and perspiration on the other.

One of the most important physiological measurements showing general condition is the blood pressure, which is frequently reported with these men. The average blood-pressure curves show systolic, diastolic, and pulse pressure. All three curves have much the same trend, namely, a distinct falling off up to November 25, with a tendency for minimum values appearing shortly thereafter, then a slight rise in systolic and diastolic pressure to January 12, after which, although the systolic and diastolic pressure curves are parallel, the pulse pressure is in the opposite direction. Pronounced reductions of all three factors are worthy of special emphasis.

Pulse-rates were recorded frequently throughout the entire series under several conditions. The normal pulse-rate was observed with the subject lying in the morning in the post-absorptive condition. (See lower part of figure 124.) The curve shows a distinct tendency towards a fall in the first part of the experiment, a plateau at the low level in November, a sharp fall from a higher level following the Christmas recess, and a slight rise toward the end of the experiment.

The important relationship between the pulse-rate and muscular work is indicated by the records computed from Professor Johnson's data, with the subject lying 1 minute before work, 1 minute after work, and the percentage increase 1 minute after work. The pulse-rate 1 minute before work, although at a distinctly higher level, is obviously more or less comparable with the pulse-rate obtained in the morning with the subject in the post-absorptive condition. The form of the two curves is not unlike, the pulse-rate 1 minute before work showing a decrease in the early part of the experiment, followed by a pronounced rise, with a striking increase immediately after the diet restriction ceased. This great increase was followed by a distinct drop following more normal eating.

The pulse for 1 minute after work on the ergometer shows up to December 8 very much the same trend as do the other pulse-rate curves. On December 10 there is a large increase and immediately following the return from the Christmas recess there is a pronounced fall to the end of the restricted-diet period. The striking increase after the restricted diet ends, noted with the pulse 1 minute before work, is here even more accentuated.

As an index of the reaction of the heart to a definite amount of work, the percentage increase in the pulse-rate 1 minute after work ceases is of interest, this representing in a sense the increment of the pulse-rate expressed in percentages for accomplishing a definite amount of work. This curve shows an extremely irregular contour, the highest point being reached about November 15, the lowest point just before the end of the observations. In comparing the number of minutes required for the pulse-rate to return to the normal after a definite amount of work, it appears that the curve for this factor and that for the percentage increase 1 minute after the ergometer riding are more or less parallel, and this is true until the return from the Christmas recess. After this point the curves are in most instances opposed to each other. It is worthy of note that with the percentage increase 1 minute after work there is a great decrease on the whole after the diet restriction ceases and a high point in the time required for the pulse-rate to return to normal after work, although the absolute maximum is noted on November 14.

Since the gaseous metabolism plays so important a rôle in our study of the total metabolism, the factors entering into the gaseous metabolism, as well as the heat calculations therefrom, are represented by several curves in figure 124.

The average total basal heat production for this group of men per 24 hours may first be considered. Although there are very wide fluctuations from day to day, as indicated by the rise and fall in the curve, the general trend is distinctly downward, save for the high points on November 26 and December 10 following the uncontrolled Sundays and likewise the initial high point following the Christmas recess in the early part of January. Thereafter during January there is a steady decline, with a minimum on January 24 and a tendency to a slight rise thereafter. Since the body-weight was changing throughout the experiment, it is quite obvious that not only the total heat per 24 hours should be considered, but particularly the heat per unit of body-weight and likewise in this homogeneous group of subjects the heat per square meter of body-surface. The curves assigned to both of these factors show remarkable uniformity and agree in the main with the total heat-production curves—a pronounced drop during the first weeks of the season, sharp rises on November 26, December 10, and after the Christ-

mas recess, with a tendency to fall thereafter, and a fair approximation to a level at the end of the period.

When one considers these measurements of metabolism as a whole and the factors of circulation and respiration, it is astonishing what regular pictures they present when compared with the body-weight and, indeed, with the intake of food. The entire picture shows the depression of all activities during the early part of the session, characteristic rises following the recuperation period during the Christmas recess, a rather sharp fall thereafter, with a tendency towards constancy during the month of January. Certain observations that were made after the period of low diet ceased show a pronounced rise in the pulse-rate, lying before riding, the pulse-rate 1 minute after riding on the ergometer, and a very great rise in the body-weight. This implies that the correlation between actual body-weight and these various factors is very close.

It is certainly clear that during the period of transition, when the body-weight was rapidly falling, all of the factors of metabolism and all of the physiological activities were markedly depressed. When the body-weight finally reached a level, namely, during the month of December and the latter part of January, there was a distinct tendency for these activities also to assume a level, although they are by no means absolutely comparable. With the resumption of increased food intake at the end of the experiment, the two factors measured both followed the body-weight, indicating a pronounced increase.

It is also of great significance to note here the two neuro-muscular processes that have been charted, namely, the number of finger movements made in 10 seconds and the eye movements as recorded in the length of time required to move the eye through an arc of 40°. The speed of the finger movements, which has been shown in an earlier research from this Laboratory to be representative of motor coordination, decreased definitely. At about the Christmas recess there was somewhat of a recovery and evidence of a distinct spurt on the last day of the experiment. The eye movements, which have likewise been shown to be characteristic motor coordinations, distinctly increase in the time required for a definite movement from the day when the observations were begun, namely, October 28, to the last day of the series, this increase being progressive and reasonably regular.

The general picture presented by this chart is a depression of the physiological, particularly the metabolic, activities, throughout the greater part of the time. This is likewise true with regard to the two neuro-muscular processes here charted. That these are in large part affected by the state of nutrition is shown by the close relationship between the various curves and the body-weight curves, and, incidentally, the food-intake curve. In view of the close relationship between pulse-rate and metabolism, and in the absence of metabolism measure-

ments after the return to normal diet, the great increase in pulse-rate accompanying the great increase in body-weight may legitimately indicate that there was likewise a corresponding increase in the metabolic processes, in all probability closely correlated with the actual body-weight curves. It is important to note, however, that the body-weight curves here have no particular significance *per se* other than as a general index of the nutritional level upon which the body was living.

Finally, attention must be again called to the pronounced accumulative loss of nitrogen with low diet, averaging for these 9 men 175 grams at the end of the 4 months of the experiment.

In interpreting this loss, we must give consideration to the figures obtained for *Tom*, although he was not included in the chart. Tom's nitrogen loss was but 45.74 grams for the entire period, while the average for the other 11 men was 175.0 grams.[1] If our theory with regard to the nitrogen stimulation is sound, one would expect normally to find a less pronounced effect on metabolism with *Tom* than with any of the other men. As the data were being prepared it appeared that there was no profound difference between the men on this basis. A more careful analysis of the data given for *Tom* shows that the total metabolism of this subject fell off very markedly, as indeed did the metabolism per kilogram of body-weight and per square meter of body-surface. Hence we have with *Tom* identically the same picture noted with all the other members of the squad, although his loss of nitrogen was on the whole but one-fourth that of the average for the 11 other members of the squad and but one-fifth that of 3 other members of the squad. At first sight this would appear to be a distinct argument against the nitrogen-stimulation theory. On the other hand, we must point out that, at least during January, *Tom* was in a distinctly poor physical condition. In fact, he was quite wretched during part of December and was operated on for hemorrhoids. No member of the squad seemed to find more difficulty in reducing his weight than he did. He presented a distinctly exceptional case throughout the entire period of observation. As frequently stated, he was the most sedentary in habit of the men in the squad. In view of the direct findings with *Tom*, therefore, we must advocate the nitrogen-stimulation theory with a certain degree of caution.

The picture presented by these men on reduced diet is similar in certain ways to that noted with diabetics who have been undergoing the Allen fasting treatment. Prior to the Allen treatment the metabolism is very high, being on the average 15 to 20 per cent higher than that of normal individuals of equal height and weight. Following the Allen treatment the metabolism becomes very much reduced. Not only does it fall to normal, but is actually lower than that of normal individuals of the same height, weight, and age. The dietetic régime of the

[1] It should be noted that these figures are for the entire period of the experiment, while those in table 71, p. 351, do not include the last week.

diabetic, together with the course of the disease, almost invariably results in a great loss of fat and not a little nitrogenous tissue; hence we believe that the loss of nitrogen as well as loss of flesh in the diabetic contributes towards this lowered metabolism after the cellular stimulus of acidosis has been removed by the Allen fasting treatment.

### CALORIC REQUIREMENT FOR WEIGHT MAINTENANCE.

In the discussion of the caloric intake at weight maintenance (see p. 283), emphasis was laid upon the fact that if the body-weight were held at a constant level for a sufficient length of time (probably months rather than weeks), the net caloric intake could be rationally taken as a measure of the caloric requirement.

Certain difficulties were experienced in finding sharply marked periods of body-weight maintenance covering a considerable length of time in this series of tests, and in no other phase of the research do we regret more the necessity for the uncontrolled period during the Christmas recess. There were, however, two periods of reasonably constant weight which appear on the several charts for Squad A. From an inspection of these data we inferred that weight maintenance at the lower level was held with net calories ranging from 1,600 calories for *Kon*, *Pec* and *Tom* to 2,500 calories for *Can*. The average for the squad was approximately 1,950 net calories. Since the intake prior to diet restriction was somewhat over 3,000 calories, and Squad B, living under substantially the same conditions aside from diet, required nearer 3,800 calories, it can be seen that the diet for Squad A at these periods of weight-maintenance was a reduction of from one-third to nearly one-half of the normal diet.

Emphasis must be laid again, however, upon the fact that the body-weight is an extremely unsatisfactory and indeed crude index of caloric needs, unless maintained for a much longer period of time than was possible in these experiments. Recourse was had, therefore, to other criteria.

### BASAL GASEOUS METABOLISM.

From two entirely independent types of respiration experiments certain fundamental data were available to show profound alterations in basal metabolism of all of these subjects following the reduction in diet. These reductions in basal metabolism were not only absolute—that is, each member of the squad had a basal metabolism very much lower at the end of the experiment than at the beginning—but they were likewise relative, for the basal metabolism on both of the two usual comparison bases, namely, the heat production per kilogram of body-weight and per square meter of body-surface, showed reductions approximating 15 to 20 per cent. On the more logical method of comparison of the basal metabolism with the predicted values from a series of tables based upon an extensive study of normal data obtained in this Laboratory, it would likewise seem that whereas these men at the

beginning of the experiment showed a normal basal metabolism perceptibly higher on the average than that predicted for men of equal weight, height, and age, at the end of the test they all showed strikingly lower values than the predicted values from the analysis of a large group of normal people. Under the circumstances, therefore, the evidence is clear that the reduction in basal metabolism is a real one. The fact that the body-weight index implied a maintenance caloric requirement over one-third or nearly one-half that prior to diet reduction, while the gaseous metabolism suggests a lowering approximating only 15 to 20 per cent, is somewhat difficult to explain other than on the ground that the body-weight data used for comparison were for altogether too short a period. From an analysis of the chart it can be seen that the influence of the reduced diet on all factors was a progressive one, with a rather rapid effect shortly after the reduction in diet began, and a tendency towards constancy coincident with constancy in body-weight.

Emphasis throughout this entire monograph has been laid upon the basal metabolism. We have not infrequently been taken to task by thoughtless critics of previous reports, who have maintained that the basal metabolism should be expressed only in periods of minutes or hours, and the length of time for which it should be expressed is determined solely by the length of the experimental period upon which the measurement is made. In the last analysis the basal metabolism of a given individual is the most important factor in his energy transformations for the 24 hours. If this is once known, the superimposed values for activities greater than lying are readily and with reasonable accuracy computed. It thus becomes of special interest to compute the probable daily caloric requirement of this group of men at the end of their diet test. For this purpose we have computed the values for the last 3 days and give the results in table 202. From this it can be

TABLE 202.—*Calculation of probable average heat output per 24 hours during last three days of experiment—Squad A.*

| | cals. |
|---|---|
| Basal heat per 24 hours (computed)[a] | 1,367 |
| "Cost of digestion" (2,486 cals.[b] × [c]0.06) | 149 |
| Heat output due to sitting ([d]11 hrs. × $\frac{1367}{24}$ × [e]0.10) | 63 |
| Heat output due to walking ([f]6.7 miles × [g]56) | 375 |
| Heat output due to exercise greater than walking ([d]1 hr. × $\frac{1367}{24}$ × [e]4.00) | 228 |
| Total | 2,182 |
| Average net calories per day[b] | 2,245 |

[a]See table 128.
[b]Computed from tables 46 to 58.
[c]Benedict and Carpenter, Carnegie Inst. Wash. Pub. No. 261, 1918, p. 343.
[d]Computed from table 194.
[e]Increase in heat output above basal for exercise greater than walking and for sitting assumed to be 400 per cent and 10 per cent respectively.
[f]Computed from daily records of walking (pedometer).
[g]Heat output above basal per mile of level walking; computed from data in tables 142 and 128.

seen that the basal heat per 24 hours was 1,367 calories. On these days there was an average gross intake of 2,486 calories. It has been found by Dr. T. M. Carpenter,[1] of this Laboratory, in recent extensive research, that an average figure for the excess heat resulting from the ingestion of mixed diet is 6 per cent of the gross energy intake. This may be stated to be the "cost of digestion." Under these conditions 149 calories represents the "cost of digestion" for this period.

As outlined in previous sections, the basal metabolism assumes the individual to be lying down without food in the stomach. The extra heat due to the ingestion of food has already been accounted for as "cost of digestion." From the carefully kept records of these men, the number of hours during which they were sitting has been recorded and averages 11 hours for these 3 days. While many writers ascribe no value to the difference between lying and sitting positions, particularly if the subject be carefully adjusted in a steamer chair, it seems reasonable to consider 10 per cent as a probable factor for the increase in the metabolism, this being substantiated by a large amount of experimental evidence.[2] The per hour figure for the basal value is 57 calories; 10 per cent of this value, multiplied by 11 hours, will therefore give 63 calories for the extra heat output due to the sitting position.

From the pedometer records these men showed an average mileage of 6.7 miles per day for the 3 days (January 30 and 31 and February 1). Extensive data on the energy requirements for horizontal walking, secured in the treadmill experiments (see p. 533) give accurate figures for computing the average caloric requirement for walking 1 mile. It has thus been found that the extra energy above basal for walking 1 mile would mean, at this stage of the diet restriction, 56 calories. This multiplied by the daily mileage of 6.7 miles equals 375 calories for the activity of walking.

In addition to the walking, the men reported on the average about 1 hour exercise more active than walking. With this factor we must make several rather debatable assumptions. An examination of the protocols shows that the men not infrequently included in this exercise certain of the simpler gymnastic exercises, such as were shown in the moving pictures, etc.; also other work which usually calls for severe work for short periods but relatively long periods of rest.. These activities were recorded as work greater than walking. It seems to us reasonable to assume for this exercise an increased output of heat above basal amounting to 400 per cent. The basal value was 57 calories per hour; 400 per cent of this for 1 hour would therefore amount to 228 calories.

[1]Benedict and Carpenter, Carnegie Inst. Wash. Pub. No. 261, 1918, p. 343.
[2]Emmes and Riche, Am. Journ. Physiol., 1911, 27, p. 406; also Soderstrom, Meyer, and Du Bois, Arch. Intern. Med., 1916, 17, p. 872.

We thus have a total energy output, computed on this basis, of 2,182 calories. The element of greatest uncertainty in the whole computation is admittedly the last factor, namely, the energy due to exercise greater than walking. Possibly, also, the increase above basal due to the sitting should be somewhat greater than it is, for one can conceive of students giving off a very considerable amount of heat when sitting and gesticulating. A recent series of experiments at the Nutrition Laboratory with several groups of Simmons College students has shown that reading aloud has a strikingly small effect upon the quiet resting metabolism, so we are inclined to think that our figure of 10 per cent is not far from correct. A comparison of this total figure of 2,182 calories with the average net calories in the diet for these 3 days (2,245 calories) is of interest. This agreement is in all probability a fortuitous one, as it would assume a long-established body-weight, which previous discussion has shown was not actual, especially on these last few days. We introduce this method of calculation, however, in part to illustrate the great significance of an accurate knowledge of the 24-hour basal requirement as the foundation for computing the probable daily heat output.

From the gaseous-metabolism measurements, therefore, which show a profound reduction in the basal metabolism on the two different types of apparatus and from the dietetic intake as calculated from the net calories, it is clear that the energy requirements of these men were very much lower at the end of the experiment than they were at the beginning with normal diet. A computation of the probable dietetic requirements of these men during the last three days of the diet seems to substantiate fully the inferences drawn from the other criteria, and it is quite clear that these men were subsisting upon a diet fully one-third less than that normally required. The full significance of this, however, lies not so much in the fact that there was an actual reduction of one-third, but that it implies distinctly that there must have been a proportionately great reduction of the energy demands for work other than the basal maintenance. The results obtained in the treadmill experiments showed clearly that the energy for forward progression, *i. e.*, the amount of energy required to move 1 kilogram 1 horizontal meter was appreciably lower when the men were on restricted diet than with normal diet. In connection with that discussion it was pointed out that although we could speak with certainty only of this particular type of muscular work, yet we have every reason to believe that the same efficiency of muscular coordination would obtain with other types of muscular work. This suggests a greatly lowered energy requirement for all of the activities of the day not merely in the lying position and post-absorptive condition, nor only when walking on the treadmill, but likewise in all the extraneous activities entering into the daily life.

## PRACTICAL CONSIDERATIONS.

As a result of the extensive scientific findings recorded in the several chapters of this discussion, this research as a whole, we hope, makes some important contributions not only to abstract science, but certain of the data supply legitimate bases for practical use in periods of stress such as obtained during the recent world war. The fundamental possibility of completely lowering the nutritional level so as to produce profound alterations in the gaseous metabolism, blood pressure, pulse, and practically all physiological functions opens a new field for the study of physiology at a low nutritional level. The fact that the whole picture was presented with striking clearness by Squad B after a relatively few days of low diet makes it not only possible but practicable to duplicate the experimental conditions easily and to refine the study of any one of the many scientific problems presented by this research. Several of these have already been indicated in our text. We regret particularly not having secured some evidence with regard to the stimulating effects of foodstuffs at this lower level, for such study should contribute materially to an explanation of the cause of the excess heat production following food ingestion. It is not impossible that many factors which are now studied on the normal nutritional level would be considerably accentuated by being superimposed on the lower level. A complete study of the character of the blood nitrogen is of course imperative. Further and more intricate studies of pulse and blood pressure, and their reactions to posture and both moderate and severe work, should also prove profitable lines of study.

Without attempting to catalogue any considerable number of these abstractly scientific problems, we would call attention to the possibilities of the therapeutic use of this procedure, since we have here two pronounced factors which are popularly supposed to influence perturbed metabolism. One of these, the removal of an excessive amount of nitrogen by the simple method of producing undernutrition, should have most important bearings upon many pathological conditions. Second, the profound lowering of the total metabolism, which has already been found in the Allen fasting treatment for diabetics to have great therapeutic effectiveness, will doubtless be extended to other pathological cases. These are problems primarily for the clinician. The dietetic procedure is extraordinarily simple, is in no particular sense strenuous or painful, and the condition of lowered nitrogen and lowered metabolism can be rapidly produced in a few weeks. The untoward influence of both procedures upon norma' healthy man is so slight as to indicate that danger, if any exist, must be remote. The beneficial effects in many pathological cases of removing large amounts of surplus nitrogen and of lowering the metabolism perceptibly will, it is confidently believed, be demonstrated in the near future.

The loss in weight of all of our subjects was a resultant of the restricted diet and the relatively active daily program. After the short periods of excess food on the free Sundays or holidays, the loss in weight was accentuated by severe physical exercise. The reduction in body-weight primarily by excessive physical exercise is also a problem that, in the light of the present research, assumes new significance; a complete interpretation of the physiology of weight reduction can not be made unless this factor has been thoroughly tested. A practical application of the principles laid down in this research may be found, however, in the question of moderate reduction cures. With the weight reduction produced by these men, either absolute or percentagewise, no serious physiological effects were noted. A word of caution, however, should be inserted, for, as McKenzie[1] has pointed out, weight reduction without accompanying physical exercise is liable to cause a loss of bodily power; furthermore, in connection with the loss of protein, when loss of weight is produced without due regard to keeping up the general tone of the body by muscular activity, constipation, hernia, and gastroptosis, particularly in middle-aged and excessively fat women, may occasionally occur. Although the rapid absorption of fat has occasionally caused displacements of the kidneys and uterus, the resulting symptoms have usually not been more troublesome than the obesity itself. For moderate weight reductions of 10 per cent it is safe to predict that even such rare occurrences may not be noted. Further weight reduction should be carried out only with the constant supervision of a competent physician.

Entirely aside from the laboratory and clinical suggestions arising from this research, we should consider the influence of an observation of this kind upon the feasibility of general dietetic restrictions as a food-conservation measure. Judging superficially from the appearance of these men at the end of their long period of restricted diet and from the amount of their intellectual and physical activity, one could assert almost with certainty that a reduction of total caloric intake of one-third was an assured possibility. Certain objections to this have been cited in our discussion. Of these the picture of secondary anemia indicated by the blood findings, the marked repression of all normal sex expression, the mental unrest and dissatisfaction experienced by many of these men should all be seriously considered. Dr. Minot believes that the anemia would not progress much farther with continuance of this diet. The absence of sex interest has an important bearing on the subject of the propagation of the race. It is possible that nature is insistent that the metabolic level found in practically all normal individuals is that best adapted for propagation and that reduction in this level can only be made at a sacrifice of sex interest and

[1]McKenzie, Exercise in Education and Medicine, Philadelphia, 1915, 2d ed. p. 530.

reduction of propagation. These warnings must certainly be heeded. Precisely the same factors that reduced normal sex expression in these men may, however, be of extreme practical importance in pathological phases of sexual perversions.

The introspection shows clearly that not a little of the mental unrest was caused by the fact that others were eating liberally and freely and the social element was removed or repressed.

Certain possible procedures that in times of stress might be justifiably recommended, at least as war measures, have been considered recently in reporting some of the data from this research.[1] This is not the place to enter into any discussion of the practical application of these diets to immediate economic national problems. It is, however, perfectly justifiable to make conclusions as to the practicability of a reduced diet in food stringencies. Entirely aside from war or any factors pertaining thereto, food stringencies will inevitably occur throughout the world as a result of accident, floods, climatic disturbances, etc. To instill into the world at large a belief that a pronounced lowering of rations is not necessarily accompanied by a complete disintegration of the organism and collapse of mental and physical powers may, after all, be of real service. A reduced ration may be a minimum, but this is far from saying that it is an optimum. Experimental evidence has accumulated in sufficient amounts to justify a serious consideration of a material reduction in the intake of protein, which is one of the most expensive factors in human food. It is not clear that a low-protein diet is harmful. Indeed, much of the evidence now points to the fact that a low-protein diet is without harmful effects upon the organism.

One of our unsolved problems in this research is the relationship between body protein and metabolic level. If the lowered general metabolism is due to the absence of protein in the body—and our evidence points strongly towards this—we may then argue that while in times of stress the minimum and lower level is justifiable and reasonably safe, in times of plenty the optimum is a higher protein level. The reduction of body-weight without loss of body-nitrogen is a scientific situation that should be thoroughly investigated. Our data throw no light on this subject. Obviously the diet could be so adjusted as to keep up the supply of body-nitrogen for the most part and still draw from body-fat. Until experiments of this type are made with accuracy and in sufficient numbers to settle this question without doubt, the amount of the optimum protein intake must be held in abeyance. For a tentative war measure the question of low protein need not seriously be contested. The recent marvelous developments as a result of the study of the so-called "food accessory substances"

[1] Benedict, Proc. Am. Phil. Soc., 1918, 57, p. 479.

lead us to believe that instead of devoting an undue amount of time to fictitious "nitrogen balances" and an attempt to curtail nitrogen to an extraordinarily low point, the character of the nitrogenous material ingested, including the food accessories, should be carefully considered, and then and not until then can the ultimate reduction of protein be properly studied.

In connection with the study of low protein and the value of the surplus protein of the body, a complementary condition should be studied in which, after the reduction in protein and its concomitant body-loss, there should be realimentation with low nitrogen intake to minimize nitrogen storage but accentuate the return to normal weight. Under these conditions the true value of the nitrogen storage to the body would be clearly shown. Furthermore, the level of nitrogen equilibrium on a diet with very low nitrogen and the normal calories for weight maintenance should be established and carefully explored. For all practical purposes, however, it is clear that the so-called low-protein diet is perfectly justifiable as a war measure and in all probability is a logical procedure that can not be accompanied with any untoward effects, even by long-continued practice. Just what this level should be remains to be demonstrated.

Our evidence seems to show that, at least with American young men, the nitrogen excretion in urine is much lower than has been commonly supposed. Whether this speaks for a nitrogen metabolism that has always existed, or whether it is due to the fact that the agitation for low protein has been gradually impressing itself upon the American dietetic habits, we can not state. A nitrogen excretion with normal men of 9 grams of nitrogen, *i. e.*, 0.15 gram per kilogram of body-weight, is a minimum level certainly well above any danger-line.

We may say, in summarizing, that protein curtailment is an assured and physiologically sound procedure, and a reduction in calories is possible for long periods, but definite and significant disturbances of blood composition, normal sex expression, and neuro-muscular efficiency, and the appearance of mental and physical unrest are deterrent factors in too sweeping generalizations as to the minimum calories being synonymous with an optimum level.